Survey Results of Green Sea Urchin (*Strongylocentrotus droebachiensis*) Populations in Queen Charlotte Strait, British Columbia, October, 2003 and November, 2004

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SURVEY RESULTS OF GREEN SEA URCHIN (*Strongylocentrotus droebachiensis*) POPULATIONS IN QUEEN CHARLOTTE STRAIT, BRITISH COLUMBIA, OCTOBER, 2003 and NOVEMBER, 2004

by

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ABSTRACT

Waddell, B. J., and Perry, R. I. 2006. Survey results of green sea urchin (*Strongylocentrotus droebachiensis*) populations in Queen Charlotte Strait, British Columbia, October, 2003 and November, 2004. Can. Tech. Rep. Fish. Aquat. Sci. 2633: ix + 73 p.

This report presents the results of two green sea urchin (*Strongylocentrotus droebachiensis*) surveys undertaken jointly between Fisheries and Oceans Canada (DFO) and industry (West Coast Green Urchin Association - WCGUA) in Queen Charlotte Strait, British Columbia, in October, 2003 and November, 2004. These surveys are part of a continuing series, starting in October, 1995, whose long-term objectives are to assess variability in green sea urchin populations, and to monitor impacts due to a commercial fishery. The surveys were conducted prior to the opening of the commercial green sea urchin fishing season, and were undertaken at three sites, which included areas open or closed to commercial fishing. Surveys were conducted by SCUBA divers, using the transect-quadrat method. Data were collected on size and abundance of green sea urchins, gonad weight and quality, and on the depth, substrate and vegetation; results are presented for three size classes of urchins.

The biomasses and mean densities of legal-sized green urchins at the commercially fished site (the Stephenson Islets) have fluctuated over the series of surveys, but have generally increased over time. The highest biomass and mean density of legal-sized ($\geq$ 55 mm test diameter (TD)) urchins of all the surveys at this site were observed in October, 2003, but these variables decreased in November, 2004. The biomass and mean density of legal-sized green urchins at one of the non-fished locations (the Plumper Islands) also showed the same general pattern. The biomasses and mean densities of sublegal-mature (25 mm $\geq$ TD $<$ 55 mm) urchins were among their highest levels at the Stephenson Islets and at the Plumper Islands in November, 2004. The biomasses and mean densities of immature ($<$ 25 mm) urchins increased in October, 2003 and were at their highest levels of all surveys at all three sites in November, 2004, suggesting a successful settlement occurred in 2003 and a second, perhaps larger settlement followed in 2004.

The fishing exploitation of legal-sized green urchins at Stephenson Islets was 0.14 $\pm$ 0.02 for the 2003/04 fishing season and 0.12 $\pm$ 0.02 for the 2004/05 fishing seasons, average values over the series of surveys. However, these ratios do not adequately reflect the large changes that occurred in the green urchin population dynamics and fishery harvests between the October, 2003 and November, 2004 surveys.

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RÉSUMÉ

Waddell, B. J., and Perry, R. I. 2006. Survey results of green sea urchin (*Strongylocentrotus droebachiensis*) populations in Queen Charlotte Strait, British Columbia, October, 2003 and November, 2004. Can. Tech. Rep. Fish. Aquat. Sci. 2633: ix + 73 p.

Nous présentons les résultats de deux relevés de l'oursin vert (*Strongylocentrotus droebachiensis*) menés conjointement par Pêches et Océans Canada (MPO) et l'industrie (West Coast Green Urchin Association - WCGUA) dans le détroit de la Reine-Charlotte, en Colombie-Britannique, en octobre 2003 et novembre 2004. Ces relevés s'inscrivent dans le cadre d'une série de relevés qui ont débuté en octobre 1995, dont les objectifs à long terme sont d'évaluer la variabilité des populations d'oursin vert et de surveiller les impacts de la pêche commerciale de cet échinoderme. Les relevés ont été effectués avant l'ouverture de la saison de pêche commerciale à trois endroits, y compris des endroits où elle y était autorisée et des endroits où elle y était interdite. Des plongeurs équipés de scaphandres autonomes ont utilisé la méthode des transects et des quadrats pour recueillir des données sur la taille et l'abondance des oursins verts, le poids et la qualité des gonades, ainsi que sur la profondeur, le substrat et le couvert végétal. Nous présentons les résultats obtenus pour trois classes de taille d'oursin.

La biomasse et la densité moyenne des oursins verts de taille réglementaire aux lieux de pêche commerciale (îlots Stephenson) fluctuent au fil de la série de relevés, mais ces variables augmentent généralement au fil du temps. Pour l'ensemble des relevés, la biomasse et la densité moyenne les plus élevées des individus de taille réglementaire (diamètre du test $\geq$ 55 mm) sont observées en octobre 2003, mais elles montrent une baisse en novembre 2004. La biomasse et la densité moyenne des individus de taille réglementaire à un des lieux non exploités (îles Plumper) montrent aussi la même tendance. La biomasse et la densité moyenne des individus matures de taille non réglementaire (25 mm $\geq$ diamètre du test < 55 mm) relevées en novembre 2004 aux îles Plumper et aux îlots Stephenson s'inscrivent parmi les plus élevées. La biomasse et la densité moyenne des individus immatures (diamètre du test < 25 mm) montrent une augmentation en octobre 2003, se situant à leur plus haut niveau de la série de relevés et pour les trois endroits en novembre 2004, ce qui suggère l'établissement fructueux de larves sur le fond en 2003 et peut-être à nouveau, mais en plus grand nombre, en 2004.

Le taux d'exploitation des oursins verts de taille réglementaire aux îlots Stephenson se chiffre à 0,14 ± 0,02 pour la saison de pêche 2003-2004 et à 0,12 ± 0,02 pour la saison 2004-2005, soit des valeurs moyennes pour la série de relevés. Ces pourcentages ne reflètent toutefois pas adéquatement les grands changements qui se sont produits dans la dynamique des populations d'oursin vert et les récoltes commerciales entre les relevés d'octobre 2003 et de novembre 2004.

INTRODUCTION

The commercial green sea urchin (*Strongylocentrotus droebachiensis*) fishery has existed in British Columbia since 1987. Hand-picking by divers is the only method allowed to harvest this species. It is currently managed using a minimum size limit of 55 mm test diameter (TD), by restricting areas and fishing seasons (usually open from November until March or April), a limited entry licensing scheme, area quotas, and by an Individual Quota (IQ) system. Fishers are required, as a condition of licence, to complete harvest logbooks and charts and submit them to Fisheries and Oceans Canada (DFO). The logbooks contain information on the dates and locations that green urchins were caught, divers' names, how long fishing was conducted each day (i.e., effort), diving depths, and the total weight of urchins removed (i.e., catch). Up until 1996, these, along with sales slip data, have been the only sources of B.C. data available upon which DFO stock assessments and management decisions have been based. These data are of variable quality because of changes in fishing practices and the aggregating nature of green sea urchin distributions. The harvest logbooks also do not contain information on sublegal-sized urchins, size frequencies of the whole population, densities, roe quality and quantity, or habitat associations. Therefore, a survey protocol was developed to study interannual variability and the impacts of fishing on the green sea urchin populations. The survey design includes a site open to commercial harvesting (and consistently fished) and two nearby sites closed to commercial fishing. Surveys were conducted in October, 1995 and March, 1996 (Waddell *et al.* 1997), November, 1996 and February, 1997 (Waddell *et al.* 2002), November, 1997 and March, 1998 (Waddell *et al.* 2003), and November, 1998, 1999, 2000, 2001 and October, 2002 (Waddell and Perry 2005) to obtain this crucial information. By coordinating surveys that involved all parties with interests in the green sea urchin fishery, i.e., DFO, First Nations (first two years of surveys) and the commercial industry, there has been improved confidence and acceptance of these data. The current report presents the data collected from two cooperative surveys performed by DFO and industry (West Coast Green Urchin Association or WCGUA) in October, 2003 and November, 2004. An overview and interpretation of all of these surveys will be presented in a future paper.

The long-term objectives of these green sea urchin scientific surveys are to monitor population changes and to assess the impacts of the fishery on green sea urchin populations at a key fishery location. To do this, green sea urchin densities, size measurements, and samples for gonad quantity and quality were obtained, both in areas open and closed to commercial green sea urchin fishing, prior to the opening of the commercial fishery. All of the surveys have been conducted at the same location in Pacific Fisheries Management Area 12 (or PFMA 12 or Area 12, where the majority of the fishery occurs), in Queen Charlotte Strait, near Telegraph Cove (Figs. 1a-1c). The Stephenson Islets met the criterion for the survey site open to commercial fishing because fishers have historically found this site to have consistently high numbers of legal-sized green sea urchins. Stubbs Island and the Plumper Islands met the criterion for monitoring population changes due to environmental variations, and are located close to the Stephenson Islets. Stubbs Island and the NW section of the Plumper Islands have been closed to commercial fishing (for research purposes) since the fall of 1995.

In the first three initial years of these surveys, (i.e., from fall 1995 to spring 1998), there was a survey just prior to the opening of the fishery (which was usually in mid-November), and

then another survey shortly following the closure of the fishery (which was usually in mid-March). The length of the opening of the fishery in Area 12 varied from year to year, and was occasionally closed before the end of the season due to the fishers reaching the allowed quota for the area. Due to funding shortages and generally inclement weather in the spring, surveys carried out following the closure of the fishing season have been discontinued since March, 1998. Surveys have been conducted every fall since that time. Both of the surveys discussed in this report were conducted just prior to the opening of the commercial green sea urchin fishery.

METHODS

(a) DATA COLLECTION – FIELD AND LAB

Two surveys were undertaken, one from October 29-31, 2003, the other from November 2-3, 2004. The green urchin surveys were designed, organized and supervised by DFO, and costs were supported by both DFO and industry. In each survey there were two dive teams (i.e., two boats), each with one industry and one DFO diver, one boat driver (industry or DFO), one dive tender (industry), and one observer/recorder (DFO). During both of these surveys, there were nine transects surveyed for green sea urchins in the Stephenson Islets (50°34.5' N, 126°49.5' W), at the north end of Johnstone Strait, near Telegraph Cove and Weynton Passage (Figs. 1b and 2a), three transects at nearby Stubbs Island (50°36.2' N, 126°49.2' W; Fig. 1c), and one to three transects in the Plumper Islands (50°34.6' N, 126°48.0' W; Figs. 1c and 2b). In the past there have been as many as ten transects surveyed at the Stephenson Islets, four transects at Stubbs Island, and six transects in the Plumper Islands. The dive teams attempted to survey all of the same transects as in the eleven previous surveys, however, in some cases poor weather, strong currents, lack of time, or divers reaching their maximum bottom time (to avoid decompression diving), prevented all of the transects from being surveyed. Table 1 shows the survey dates, the vessels involved and the number of transects surveyed at each of the sites for each survey.

The transect positions were randomly selected during the first survey in 1995 and marked on a chart prior to arriving at the survey area (Waddell *et al.* 1997, 2002). The transects ran perpendicular to the shoreline and/or depth contours (with slight adjustments of the angle to best manage the direction of the current), starting at 10.0 m (32.8 ft) below Chart Datum (CD) and continuing up to zero CD. A computer program called "Tides and Currents for Windows" (Nautical Software Inc. 1995) was used to calculate the tide levels for every 10 minutes so that the depth to CD could be determined before each dive commenced. A weighted (lead) line was laid from shallow to deep to mark the transect, with a surface marker buoy indicating the deep end of the line. At the start of each transect, a compass bearing was taken by the divers from the marker buoy to the shallow end. Beginning at the deep end, the divers placed a 1 m^2 aluminum quadrat on the substrate beside the lead line and measured the test diameter (TD) (using calipers) of all green sea urchins within the quadrat, and counted all red (*Strongylocentrotus franciscanus*) and purple (*S. purpuratus*) sea urchins. All urchins were removed from the quadrat as they were being measured to avoid repeating measurements. An urchin was considered to be in a quadrat if one-half or more of its body was within the quadrat's boundaries. Sometimes green urchins were under rocks or in crevices, so all surfaces

were explored in order to find all sea urchins. One diver did all of the measuring while the other diver recorded the data on waterproof paper. The depth, substrate and type of vegetation were also recorded for each quadrat, and then the quadrat frame was rolled over in the direction of the lead line (or the compass bearing when lead line could not be used), and the procedure was repeated along the full length of the transect.

The surface personnel recorded the position (using a GPS) for both the start and finish of the transects, as well as the divers' start and finish times for each transect (for use in calculating depth from CD), and the weather conditions.

Green sea urchins of various size classes (small, medium and large) were randomly collected along the transect lines during the surveys for later laboratory analyses of weight and size and to examine the quality of the roe. The protocol was to measure and dissect the green urchins on the same day they were collected. However, due to circumstances, the urchins collected in October, 2003 from Transects 15, 17, 18 and 20, were kept in separate tanks and dissected from 1 to 3 days following collection. In November, 2004, all of the urchins were dissected the day following collection. For each urchin collected, the following data were recorded: test diameter; test height; total wet weight; drained weight; gutted weight (stomach and contents removed); gonad weight, colour and texture; and sex. Gonad colour was given a qualitative rating code of 0 (unknown (i.e., missing), or no gonad present), 1 (orange/yellow), 2 (yellow with other colours), or 3 (brown/red). Gonad texture was also given a qualitative rating code of 0 (unknown (i.e., missing), or no gonad present), 1 (firm), 2 (semi-firm), and 3 (flimsy).

(b) DATA ANALYSES

It was noted that the divers occasionally started surveying deeper than 10 m below CD, or they continued surveying shallower than 0 m CD. Since the area estimate for the Stephenson Islets is based on the area between the 0 and 10 m isobaths, and green urchins are usually sparse at depths greater than 10 m below CD, the divers' data were truncated to include only data collected between 0 and 10 m (33 ft) below CD for the overall density calculations, biomass, and for the density by substrate calculations. The original (unadjusted) data were used for all other calculations presented in this report.

Test diameter frequency distributions were analyzed using the software "MIX3aa" (Macdonald 1994) to identify dominant size modes under the assumption that individual modes were normally distributed (see Macdonald and Pitcher (1979), and Macdonald and Green (1988), for details). In general, initial parameters (mean, and standard deviation) were assigned by examination of test diameter frequency data distributions collected during the surveys at each site. The software "MIX3aa" was then used to estimate the proportions while keeping the mean and standard deviation parameters fixed. Next, estimates of mean, standard deviation, and proportion were calculated by varying the constraints on each until a reasonable fit to the data was established. This fit was determined by the goodness-of-fit chi-square statistical test and examination of the size frequency histogram with its fitted components. The software fit the means, proportions, and standard deviations of the size frequency distributions using the Quasi-Newton Algorithm technique (Macdonald and Green 1988). The test diameter frequency

distributions were analyzed for data obtained at Stephenson Islets, Stubbs Island, and Plumper Islands from both surveys.

In many of the analyses, the data have been separated into three different size classes: legal-sized (TD ≥ 55 mm); sublegal-mature (25 mm ≥ TD < 55 mm); and sublegal-immature (or immature; TD < 25 mm). The mature/immature size of 25 mm TD was approximated from the dissection roe quality and maturity data, in which 100% of green urchins < 25 mm were immature (no gonad present) compared with 6% of urchins ≥ 25 mm being immature.

Mean and total densities of green urchins for each transect within each of the three survey sites (Stephenson Islets, Stubbs Island, and Plumper Island) were calculated as described by Jamieson and Schwarz (1998). These surveys are characterized by the quadrats within a transect not being independent (e.g. if one quadrat has a high number of urchins, then adjacent quadrats are likely to have high numbers as well), transect lengths vary among the transects, and all urchins within each transect are counted. These features indicate a "complete cluster" sampling design with unequal-sized clusters (Jamieson and Schwarz 1998). The appropriate calculation for the mean density (of a particular size class of urchins) is:

$$\overline{D} = \frac{\sum_{i=1}^{n} U_i}{\sum_{i=1}^{n} L_i} \qquad (1)$$

and for the standard error of density is:

$$SE(\overline{D}) = \sqrt{\frac{1}{\overline{L}^2}\frac{1}{n}\frac{\sum (U_i - L_i\overline{D})^2}{n-1}} \qquad (2)$$

with n = the number of transects sampled in a particular site;

U_i = the total number of urchins of the appropriate size class in transect i, $i = 1,2,...,n$;

L_i = the total number of quadrats in transect i; and

$\overline{L}$ = $\frac{1}{n}\sum_{i=1}^{n} L_i$, the average area of the transects in the site.

Since the area of a quadrat was 1 m^2, L_i is also equal to the area of the transect.

In the results that follow, standard errors have not been calculated for the individual transects since the transect has been defined as the (cluster) sample unit, and therefore the (n-1) term in the denominator of the equation for the standard error goes to zero. In the calculation of urchin densities by depth range and substrate type, however, the quadrats have been considered as the sampling unit, and distributed among the various depth and substrate categories. This reduces (but does not entirely eliminate) the problem of non-independence among adjacent quadrats, and so standard errors about the mean densities for these classifications have been calculated using standard formulae (e.g. as found in Sokal and Rohlf (1981) and as implemented in the "EXCEL 2002" (Microsoft) statistical software package).

When calculating the "densities of green urchins by depth range", the actual depth below CD had to be determined for each quadrat, which depended on the continually changing

tide height. This was accomplished by first calculating the number of minutes spent at each tide height above CD (to rounded feet) over the length of each dive for each transect, by using the "Tides and Currents for Windows" program (Nautical Software Inc. 1995) set for every one minute. Then the tide height above CD was calculated for each quadrat by proportioning the dive time over the transect according to the number of quadrats in each transect. Once this was calculated, then the tide height above CD was subtracted from the depth gauge reading recorded for each quadrat, to give the approximate adjusted depth below CD. Note that in past reports the mean tide height above CD over a transect was calculated and then this one mean value was subtracted from all of the depth gauge readings for that transect. Also note that the depth readings are initially recorded in feet and then converted to meters for the report because the depth gauges only read in feet.

The three most abundant substrates in each quadrat were recorded, in order of prominence. The tables and figures in this report displaying the substrate data use three digit codes that represent the order of prominence and type of substrates observed. A similar recording method was used for vegetation types. However, the vegetation data were incomplete, making it difficult to interpret from the data sheets whether algae were absent or just not recorded. In addition, the divers had varying skill levels in identifying algal species, so the data were not considered reliable and are therefore not presented in this report.

The statistical software package "EXCEL 2002" (Microsoft) was used to find the best relationships (i.e. highest R^2) between TD (in millimeters) and the variables test height (in millimeters), total wet weight (in grams), and gonad weight (in grams). These were calculated from dissection data for all sites combined, and for each of the three sites separately, for both of the surveys. The majority of the calculations had the best fit when the power equation was used (i.e., $variable = \alpha(TD)^{\beta}$), therefore this was the standard equation used for all calculations. Note that samples that had gonad weights of zero were removed from the calculations.

The mean abundance of green urchins was converted to total biomass for all of the survey sites using the mean individual urchin weights (separated into three size classes), the mean densities, and the total area of each site. Rather than using a single mean individual weight for the whole sample population to convert abundance to biomass (as in Waddell *et al.* 1997), we used the following method (as in Waddell *et al.* 2002, 2003, 2005). The measured green urchins were separated into three size classes: legal-sized (TD $\geq$ 55 mm); sublegal-mature (25 mm $\geq$ TD < 55 mm); and immature (TD < 25 mm). The individual weights were calculated for each urchin measured in the field survey using the TD-weight relationships derived from the laboratory measurements, then the mean individual urchin weight ($\overline{W}_j$) was calculated for each size class (j). The standard error about the mean weight for each size class ($SE(\overline{W}_j)$) was determined by calculating the standard deviation of the mean weight and dividing by the square root of the sample size. A test for homogeneity of the regression slopes was performed to determine whether the TD and the natural log of the total wet weight relationship could be used for all sites combined (within each survey) or if the relationship for each site had to be used separately. This test was programmed in "EXCEL 2002" using equations from Zar (1984, p. 300).

The total biomass for a particular site was then calculated as

$$B = \sum_{j=1}^{3} \overline{D}_j (\overline{W}_j)(A) \tag{3}$$

where *j* subscripts the three size classes. The area (A) (from 0 to 10.0 m below CD) of each survey site was determined to be 485,200 m^2 for Stephenson Islets, 19,600 m^2 for Stubbs Island, and 223,600 m^2 for the Plumper Islands, based on a geographic information program called COMPUGRID (Geo-Spatial Systems Ltd. 1996).

The standard error of the total biomass for a particular site, which includes the uncertainties in the mean density and mean weight by size category, was calculated as:

$$SE(B) = \left[\sum_{j=1}^{3} \left[\left(\left(\frac{SE(D)_j}{\overline{D}_j} \right)^2 + \left(\frac{SE(W)_j}{\overline{W}_j} \right)^2 \right)^{\frac{1}{2}} (B_j) \right]^2 \right]^{\frac{1}{2}}, \tag{4}$$

with symbols as previously defined, and assuming that the area (*A*) (used within the calculation for B_j) is known without error. A further assumption is that the errors in mean density and mean weight, and among size classes, are independent and random.

In order to determine the impact of fishing on the stock of green sea urchins at Stephenson Islets (the roe fishery site), we calculated exploitation by the fishing industry using the following equation:

$$Expl = \frac{B_{fishing}}{B_{Nov}}, \tag{5}$$

with standard error defined by:

$$SE(Expl) = (Expl) \left[\left(\frac{SE(B_{fishing})}{B_{fishing}} \right)^2 + \left(\frac{SE(B_{Nov})}{B_{Nov}} \right)^2 \right]^{\frac{1}{2}}. \tag{6}$$

$B_{fishing}$ is the biomass removed from the Stephenson Islets by fishing, with standard error $SE(B_{fishing})$; B_{Nov} is the pre-fishery biomass at the Stephenson Islets, with standard error $SE(B_{Nov})$, defined here as either the total biomass or the biomass of legal-sized urchins from the fall surveys, and *Expl* is the exploitation of green urchins (with standard error *SE(Expl)*), defined as a proportion of the pre-fishery biomass (either total or legal-sized only). The biomass removed by the fishery ($B_{fishing}$) at Stephenson Islets was determined by examining dockside validation records and charts of fishing locations submitted with these records, and tabulating the total landings. The precise error of the dockside weight measurements for validation is unknown, but considered to be small, therefore $SE(B_{fishing})$ was set at 1% of $B_{fishing}$.

Note that EXCEL spreadsheets are used for many of these calculations, and that each result from a sequence of calculations is not rounded off. Therefore, any differences between calculations and values shown in the tables are due to rounding errors.

Green urchin densities increased over the years of the surveys, until it became difficult to measure all urchins within the time and budget constraints, and it became necessary to change the methodology. On some transect lines, instead of measuring all green urchins in every quadrat, they were measured in every second quadrat and urchins in the alternate quadrats were counted only. These unmeasured urchins (or "unknowns") were incorporated into the data analyses for these two surveys. The estimates of legal and sublegal urchins within the unmeasured urchins were calculated using the proportions of measured legal-sized and sublegal-sized urchins of all the measured urchins. These values were then added to the number of measured legal-sized and sublegal-sized urchins to calculate the total numbers of each of these size classes. These adjustments of the data to include unmeasured urchins in the data analyses were done for many of the tables, including density by transect and site, density by depth range, and the biomass estimates.

RESULTS

(a) OCTOBER 29-31, 2003 SURVEY

Nine transect lines were surveyed in the Stephenson Islets (Table 1, Fig. 1b; missing Transect 10 this survey), three transects were surveyed at Stubbs Island (Fig. 1c; missing Transect 16), and three transects in the Plumper Islands (Fig. 1c; missing Transect 21) during the October, 2003 survey. Some transects were missed due to lack of time or divers had reached their maximum bottom time allowed (to avoid decompression diving). The tide was high during most of the survey.

Size: There were a total of 517 quadrats that were surveyed in this survey, of which 326 quadrats were measured. Test diameter (TD's) measurements were taken for 2,039 urchins and another 1,376 urchins were counted. Of the total 3,415 green urchins observed in this survey, 1,510 (44.2%) were of legal size, 1,689 (49.5%) were sublegal-mature, and 216 (6.3%) were sublegal-immature (Table 2). Figure 2a shows the size frequency distribution for all the sites combined during the October, 2003 survey. When combining all the test diameters measured at all sites during the October, 2003 survey, three distinct modes best fit the distribution (X^2 = 48.0; df = 34; p = 0.0562), with test diameter means at 6, 32 and 58 mm (Table 3). The proportions of these modes were 1%, 30% and 69%, respectively. Mean TD's and weights for urchins from all sites combined were 62.9 ± 0.2 mm and 84.0 ± 0.8 g for legal-sized urchins, 41.6 ± 0.3 mm and 28.5 ± 0.5 g for sublegal-mature urchins, and 17.5 ± 0.6 mm and 2.9 ± 0.2 g for sublegal-immature urchins (Table 4).

Density: The mean overall total density during this survey (all sites combined) was 6.61 ± 0.85 urchins/m^2 (Table 5). After adjusting for unmeasured urchins, the mean overall densities were 2.92 ± 0.36 urchins/m^2 for legal-sized urchins, 3.27 ± 0.55 urchins/m^2 for sublegal-mature urchins, and 0.42 ± 0.12 urchins/m^2 for sublegal-immature urchins.

Depth: The sample mean densities of green sea urchins by depth range for all sites combined are shown in Table 6a and Fig. 3a. The data for unmeasured urchins were proportioned into the legal and sublegal estimated values by using the proportions of legal and sublegal urchins in the measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns. The highest mean total density of green urchins for all sites combined (12.28 ± 2.40 urchins/m^2) was observed in the 0.3 to 1.5 m (1 to 5 ft) below CD range, closely followed by urchins just below in the 1.8 to 3.0 m (6 to 10 ft) below CD range (11.10 ± 1.40 urchins/m^2). Both of these ranges contained high densities of unmeasured urchins. The highest density of legal-sized green sea urchins (6.98 urchins/m^2) occurred in the 0.3 to 1.5 m (1 to 5 ft) below CD depth range, and the highest density of sublegal-sized urchins (6.13 urchins/m^2) occurred in the 1.8 to 3.0 m (6 to 10 ft) below CD depth range. As observed in past surveys, the mean total densities generally decreased continuously with each deeper depth interval.

Substrate: Table 7a and Fig. 4a show the mean densities of green sea urchins by substrate type for all sites combined. Smooth bedrock was the most sampled substrate (181 quadrats), and smooth bedrock with boulders had the highest mean total density (37.00 urchins/m^2; 1 quadrat only), comprised of mainly sublegal-sized urchins (31.00 urchins/m^2). The substrate of smooth bedrock with crevices and boulders also had a high mean density of urchins (28.00 urchins/m^2; 1 quadrat only), but all of the urchins were unmeasured (Table 7a). When examining the data grouped for the primary substrate type, the highest mean total densities were for smooth bedrock (7.01 ± 0.69 urchins/m^2; 280 quadrats).

(i) Stephenson Islets

Size: There were 195 quadrats measured (1,395 green urchins) and 187 quadrats that were only counted (1,254 green urchins), for a total of 382 quadrats surveyed (total 2,649 green urchins) at the Stephenson Islets. After adjusting for unmeasured urchins, there were 1,071 (40.4%) legal-sized, 1,420 (53.6%) sublegal-mature-sized, and 158 (6.0%) sublegal-immature-sized urchins (Table 2). The size frequency distribution is shown in Fig. 2b. Table 3 presents the test diameter frequency analysis for the October, 2003 survey. Stephenson Islets showed the best fit (X^2 = 48.0; df = 32; p = 0.0347) with three dominant size modes with means occurring at 6, 34, and 57 mm TD. The proportions of these three modes were 1%, 34%, and 64%, respectively. Mean TD's and weights for urchins from Stephenson Islets were 61.6 ± 0.2 mm and 78.2 ± 0.8 g for legal-sized urchins, 42.2 ± 0.3 mm and 29.0 ± 0.6 g for sublegal-mature urchins, and 17.4 ± 0.7 mm and 2.8 ± 0.2 g for sublegal-immature urchins (Table 4).

Density: After adjusting for the unmeasured urchins, the mean total, legal, sublegal-mature and sublegal-immature densities at the Stephenson Islets were 6.93 ± 1.11 urchins/m^2, 2.80 ± 0.41 urchins/m^2, 3.72 ± 0.71 urchins/m^2 and 0.41 ± 0.16 urchins/m^2, respectively (Table 5). The highest total (14.32 urchins/m^2), sublegal-mature (8.61 urchins/m^2), and sublegal-immature (1.57 urchins/m^2) densities occurred at Transect 13 (Table 5). Transect 11 had the highest density of legal-sized urchins (5.25 urchins/m^2).

Depth: The highest mean total (13.94 ± 3.26 urchins/m^2) and legal-sized (7.09 urchins/m^2) densities occurred in the 0.3 to 1.5 m (1 to 5 ft) below CD depth range (n=32 quadrats; Table 6b; Fig. 3b). The densities below this depth range generally decreased with each depth

increment. The highest mean sublegal (7.22 urchins/m^2) density occurred in the 1.8 to 3.0 (6 to 10 ft) below CD depth interval

Substrate: The most frequently surveyed substrate was smooth bedrock (133 quadrats; Table 7b and Fig. 4b). The highest mean total (37.00 urchins/m^2) and sublegal (31.00 urchins/m^2) densities occurred on smooth bedrock with boulders, however only one quadrat of this substrate was surveyed. The highest mean legal density (9.00 urchins/m^2) occurred on a substrate of creviced bedrock with boulders and cobble, and the highest mean density of unmeasured urchins (28.00 urchins/m^2) occurred on smooth bedrock with creviced bedrock and boulders. Smooth bedrock was the main substrate with the highest mean overall density (7.69 ± 0.91 urchins/m^2).

(ii) Stubbs Island

Size: Green sea urchins were measured in all 55 quadrats surveyed at Stubbs Island, totalling 301 measurements (Table 2). This included 181 (60.1%) legal-sized, 93 (30.9%) sublegal-mature, and 27 (9.0%) sublegal-immature urchins. The analysis of the size frequency distribution (Table 3 and Fig. 2c) showed that there were two main frequency modes at 25 and 61 mm (X^2 = 25.7; df = 31; p = 0.74). Although the p-value indicates a non-significant relationship, visual inspection (F_y) clearly reflects two size modes. Mean TD's and weights of urchins at Stubbs Island in October, 2003 were: 65.5 ± 0.5 mm and 77.8 ± 2.1 g for legal-sized urchins; 41.9 ± 1.1 mm and 23.5 ± 1.5 g for sublegal-mature urchins; and 20.6 ± 0.5 mm and 2.5 ± 0.2 g for sublegal-immature urchins (Table 4).

Density: The mean overall total, legal, sublegal-mature and sublegal-immature densities at Stubbs Island were 5.47 ± 2.21 urchins/m^2, 3.29 ± 1.39 urchins/m^2, 1.69 ± 0.73 urchins/m^2 and 0.49 ± 0.22 urchins/m^2, respectively (Table 5). The highest mean total (9.14 urchins/m^2), legal (5.59 urchins/m^2), sublegal-mature (2.82 urchins/m^2), and sublegal-immature (0.73 urchins/m^2) densities all occurred at Transect 17, and the lowest densities for all size categories except for legal-sized occurred at Transect 18.

Depth: The highest mean total (12.00 ± 4.10 urchins/m^2) and legal (9.00 urchins/m^2) densities occurred in the 0.3 to 1.5 m (1 to 5 ft) below CD depth range (Table 6c; Fig. 3c). The highest mean sublegal density (4.00 urchins/m^2) occurred in the 0.0 to 0.6 m (0 to 2 ft) above CD depth range.

Substrate: At Stubbs Island, the substrate most frequently surveyed was smooth bedrock (20 quadrats, Table 7c). The highest mean total (10.60 urchins/m^2) and sublegal (3.80 urchins/m^2) densities occurred on a substrate of smooth and creviced bedrock (ten quadrats; Table 7c and Fig. 4c). The highest mean density of legal-sized urchins (8.00 urchins/m^2) occurred on a substrate of boulders and creviced bedrock. The main substrate with the highest mean total density (6.18 ± 1.47 urchins/m^2) was smooth bedrock.

(iii) Plumper Islands

Size: During the October, 2003 survey there was a total of 80 quadrats surveyed in the Plumper Islands, of which 76 quadrats were measured. There were 465 green urchins measured in total.

After adjusting for unmeasured urchins, there were 258 (55.5%) legal-sized urchins, 176 (37.9%) sublegal-mature urchins, and 31 (6.7%) sublegal-immature urchins (Table 2). The size frequency distribution is presented in Fig. 2d, and Table 3 presents the results of the test diameter frequency analysis. Although the plot in Fig. 2d shows three frequency modes, the model would only work for two frequency modes, occurring at 32 and 62 mm ($X^2 = 24.0$; df = 26; p = 0.58), after the left mode was deleted from the data. The mean TD's and weights for legal, sublegal-mature and immature-sized urchins were 64.6 ± 0.5 mm and 83.1 ± 1.7 g, 38.0 ± 0.7 mm and 20.9 ± 1.1 g, and 14.6 ± 1.5 mm and 2.1 ± 0.4 g, respectively (Table 4).

Density: The mean densities at the Plumper Islands in October, 2003 (after adjusting for unmeasured urchins) were 5.81 ± 1.03 urchins/m^2 for all size categories combined (total), 3.23 ± 1.15 urchins/m^2 for legal-sized urchins, 2.20 ± 0.54 urchins/m^2 for sublegal-mature urchins, and 0.39 ± 0.23 urchins/m^2 for sublegal-immature urchins (Table 5). The highest mean total (8.00 urchins/m^2) and legal (5.54 urchins/m^2) densities occurred at Transect 22, whereas the highest mean sublegal-mature (3.76 urchins/m^2) and immature (1.00 urchins/m^2) densities occurred at Transect 23.

Depth: The highest mean total (12.29 ± 3.80 urchins/m^2), legal-sized (6.43 urchins/m^2), and sublegal-sized (5.86 urchins/m^2) densities occurred in a deep depth interval of 7.9 to 9.1 m (26 to 30 ft) below CD (Table 6d; Fig. 3d). There was not the gradual decrease in total density with each increment of depth at this site as observed in most other surveys and sites, but rather an alternating decrease/increase with each depth range (Table 6d).

Substrate: The most frequently observed substrate in the Plumper Islands was smooth bedrock (28 quadrats; Table 7d). The highest mean total density (8.00 urchins/m^2) occurred on both creviced bedrock and on cobble. These were also the two main substrates with the highest mean densities (again, 8.00 urchins/m^2). The highest mean legal density (4.18 urchins/m^2) occurred on smooth bedrock, and the highest mean sublegal density (4.76 urchins/m^2) occurred on smooth bedrock with creviced bedrock (Fig. 4d).

(iv) Dissection Data

Lab measurements were performed using the same method as in October, 2002 (Waddell and Perry 2005), which is slightly different than in surveys previous to that. There were 136 green sea urchins that were randomly collected from all depths and all locations and fully measured and analyzed in the same method as in all the other surveys (Table 8). In addition, there were an extra 150 urchins (in total) that were collected from all of the sites that only had their test heights, test diameters and total wet weights measured. Therefore there are two sample sizes presented in Table 8. These additional measurements were taken in order to calculate a more accurate test diameter/wet weight relationship (i.e. providing a larger sample size, without spending an inordinate amount of time with all of the other measurements and dissections).

As in the previous survey (October, 2002; Waddell and Perry 2005), the legal-sized urchins randomly selected from Stubbs Island (n=43) had the largest mean measurements for all of the lab measurements taken, except for the mean stomach and content weight (Table 8), which was largest for legal-sized urchins from the Plumper Islands. Again, like the October,

2002 survey, legal-sized urchins randomly selected from the Stephenson Islets in October, 2003 (n=86) had the smallest mean measurements for all lab measurements taken. These results are somewhat similar to the field survey data, where the mean legal-sized test diameters were highest at Stubbs Island and lowest at the Stephenson Islets (Table 4). However, the field data showed that the mean total wet weights were largest for green urchins measured at the Plumper Islands and smallest for urchins measured at Stubbs Island (Table 4).

A test for homogeneity of regression slopes showed there was a significant difference between the slopes of the regression lines for the relationship between test diameter and the natural log transformation (to approximate normality) of the total wet weight for the three separate sites (F value = 34.47 with df = 2, 283 and $p < 0.05$). Therefore individual allometric equations ($W=\alpha TD^{\beta}$) were used for each site in the October, 2003 survey when calculating the total wet weight (in grams) from the TD (in millimeters).

The best (i.e., highest R^2) power relationships were calculated between TD (in millimeters) and test heights (in millimeters; Figs. 5 and 6), TD (in millimeters) and total wet weight (in grams; Figs. 7 and 8), and TD (in millimeters) and gonad weight (in grams; Figs. 9 and 10), for all sites combined and for each of the three sites separately, using EXCEL (see figures for equations).

Legal-sized green urchins randomly collected from the Plumper Islands had the highest percentage (50.0%) of the best quality roe (i.e., orange/yellow colour and firm texture), followed by the Stephenson Islets (37.5%), and then Stubbs Island (23.1%; Table 9). The mean roe recovery rates (total gonad weight (all grades) divided by the total drained weight of all urchins sampled) was highest for legal-sized urchins at the Plumper Islands (20.1%), followed by Stubbs Island (19.0%), and then the Stephenson Islets (15.6%).

(v) Biomass Estimates

The mean total density at the Stephenson Islets in October, 2003 (6.93 urchins/m^2; Table 5) was extrapolated over the total area between zero and 10 m below CD (485,200 m^2), to derive that there were 3,364,646 ± 540,287 green sea urchins of all sizes at this site (Table 10). This included 1,360,338 ± 198,340 legal-sized, 1,803,623 ± 342,261 sublegal-mature, and 200,685 ± 76,582 immature green urchins. Since a test for homogeneity showed there was a significant difference between the slopes of the TD-total wet weight regressions for the three sites, the TD-total wet weight relationship from the dissection data for all urchins collected only from the Stephenson Islets in October, 2003 (Fig. 8a) was applied to all the test measurements recorded in the field for the Stephenson Islets. Mean individual wet weights were then calculated for the three size classes. The mean weights per legal-sized, sublegal-mature-sized and immature-sized green sea urchin from Stephenson Islets were determined to be 78.2 ± 0.8 g, 29.0 ± 0.6 g, and 2.8 ± 0.2 g, respectively (Table 4). Multiplying the individual weights with the abundances gave total biomasses of 106.35 ± 15.52 t, 52.36 ± 9.95 t, and 0.57 ± 0.22 t for legal-sized, sublegal-mature and sublegal-immature green sea urchins at Stephenson Islets in October, 2003 (Table 10). The overall total biomass was 159.27 ± 18.44 t.

By extrapolating the mean densities (Table 5) over the total area at Stubbs Island, it was determined that there was a total of 107,265 ± 43,385 green urchins, of which 64,502 ± 27,272

were of legal size, 33,142 ± 14,293 that were sublegal-mature, and 9,622 ± 4,271 that were immature (Table 10). The mean individual wet weights, calculated using the TD-total wet weight relationship for Stubbs Island urchins only (Fig. 8b), were 77.8 ± 2.1 g, 23.5 ± 1.5 g, and 2.5 ± 0.2 g for legal-sized, sublegal-mature-sized, and sublegal-immature green urchins, respectively (Table 4). The total biomass at Stubbs Island in October, 2003 was 5.82 ± 2.15 t (Table 10). This was comprised of 5.02 ± 2.12 t of legal-sized urchins, 0.78 ± 0.34 t of sublegal-mature urchins, and 0.02 ± 0.01 t of sublegal-immature urchins.

The estimated numbers of green urchins in the Plumper Islands survey site in October, 2003, based on the calculated mean densities (Table 5), were 721,110 ± 256,332 legal-sized urchins, 491,920 ± 120,631 sublegal-mature urchins, and 86,645 ± 52,185 sublegal-immature urchins, for a total of 1,299,675 ± 229,518 green urchins (Table 10). The mean individual wet weights were calculated using the TD-total wet weight relationship for Plumper Island urchins only (Fig. 8c). They were 83.1 ± 1.7 g, 20.9 ± 1.1 g, and 2.1 ± 0.4 g for legal-sized, sublegal-mature, and sublegal-immature urchins, respectively (Table 4). The biomass estimates were 59.93 ± 21.33 t of legal-sized urchins, 10.30 ± 2.56 t of sublegal-mature urchins, and 0.18 ± 0.11 t of immature urchins, for a total biomass estimate of 70.41 ± 21.48 t (Table 10).

(b) NOVEMBER 2-3, 2004 SURVEY

Due to very strong winds, the November, 2004 survey was terminated before completion. Therefore, there was one less transect surveyed at the Stephenson Islets (Table 1; Fig. 1b; 9 transects instead of 10, missed Transect 10), one less transect surveyed at Stubbs Island (Fig. 1c; 3 transects instead of 4, missed Transect 17), and only one transect out of four was surveyed at the Plumper Islands (Fig. 1c, Transect 23; Table 1).

Size: There were 496 quadrats surveyed in total, of which 266 were fully measured. Of the total 4,745 green urchins observed during this survey, 1,003 (21.1%) were legal-sized, 3,114 (65.6%) were sublegal-mature, and 628 (13.2%) were sublegal-immature (after adjustments for unmeasured urchins; Table 2). The size frequency distribution for the whole survey is presented in Fig. 11a, and the size frequency analysis is presented in Table 3. There was only one dominant mode (41 mm) for all of the sites combined (X^2 = 159.1; df = 42; p <0.0001). The mean TD's and weights for all sites combined were 62.0 ± 0.2 mm and 84.3 ± 1.1 g for legal-sized urchins, 39.1 ± 0.2 mm and 25.0 ± 0.3 g for sublegal-mature urchins, and 19.3 ± 0.2 mm and 3.4 ± 0.1 g for sublegal-immature urchins (Table 11).

Density: In November, 2004, the mean total density for all sites combined was 9.57 ± 1.52 urchins/m^2 (Table 12). The mean overall densities (after adjustment for unmeasured urchins) for legal-sized, sublegal-mature-sized, and immature green urchins were 2.02 ± 0.27, 6.28 ± 1.36, and 1.27 ± 0.21 urchins/m^2, respectively (Table 12).

Depth: The highest mean total density for all sites combined (29.93 ± 4.12 urchins/m^2) occurred in the shallowest depth range (0.0 to 1.2 m or 0 to 4 ft above CD (Table 13a; Fig. 12a)). This was also the depth range where the highest mean legal-sized (7.74 urchins/m^2) and sublegal-sized (22.19 urchins/m^2) urchin densities occurred.

Substrate: The substrate most frequently sampled (210 quadrats) was smooth bedrock. Combining results from all sites, boulders with creviced bedrock was the substrate with the highest mean total (23.00 urchins/m^2) and legal (11.00 urchins/m^2) densities of green urchins (Table 14a; Fig. 13a; one quadrat only). The highest mean density of sublegal-sized urchins (17.00 urchins/m^2) occurred on creviced bedrock with gravel and shell (one quadrat only). The main substrate with the highest mean total density (11.36 ± 0.73 urchins/m^2) was creviced bedrock.

(i) Stephenson Islets

Size: In November, 2004 there were 195 quadrats that were fully surveyed (measured), and 230 that were counted only, for a total of 425 surveyed quadrats. After adjusting for unmeasured urchins, there were 817 (19.9%) legal-sized, 2,784 (67.7%) sublegal-mature-sized, and 512 (12.5%) sublegal-immature (or a total of 4,113) green urchins observed in the Stephenson Islets (Table 2). The size frequency analysis (Fig. 11b and Table 3) showed there were two dominant modes, at 32 mm (60.0%) and 52 mm (40.0%) (X^2 = 51.5; df = 29; p <0.0061). Mean TD's and weights for urchins from Stephenson Islets were 59.8 ± 0.2 mm and 65.5 ± 0.7 g for legal-sized green urchins, 39.5 ± 0.2 mm and 22.6 ± 0.3 g for sublegal-mature urchins, and 19.6 ± 0.3 mm and 3.2 ± 0.1 g for sublegal-immature urchins (Table 11).

Density: The mean total, legal, sublegal-mature and sublegal-immature densities at the Stephenson Islets (after adjusting for the unmeasured urchins) were 9.68 ± 1.77 urchins/m^2, 1.92 ± 0.26 urchins/m^2, 6.55 ± 1.59 urchins/m^2 and 1.20 ± 0.24 urchins/m^2, respectively (Table 12). Transect 9 had the highest mean total (18.10 urchins/m^2) and sublegal-mature densities (14.14 urchins/m^2 after adjusting for unmeasured urchins; Table 12). The highest mean legal-sized density (3.44 urchins/m^2) occurred at Transect 8, while the highest mean immature-sized density (2.20 urchins/m^2) occurred at Transect 3.

Depth: The highest mean densities for all size categories occurred in the 0.0 to 1.2 m (0 to 4 ft) above CD depth range (n=17 quadrats; Table 13b; Fig. 12b). The mean densities were: 5.41 urchins/m^2 for legal-sized urchins, 26.94 urchins/m^2 for sublegal-sized urchins, and 32.29 ± 4.66 urchins/m^2 for all size categories combined. The mean densities below this depth range gradually decreased with each depth increment, and then slightly increased at the deepest depth range surveyed (11.0 m or 36 ft below CD).

Substrate: The most frequently surveyed substrate at this site was smooth bedrock (179 quadrats; Table 14b). The highest mean total (19.00 urchins/m^2) and sublegal (17.00 urchins/m^2) densities occurred on creviced bedrock with gravel and shell, however only one quadrat of this substrate was surveyed (Table 14b and Fig. 13b). The main substrate with the highest mean overall density (11.64 ± 0.84 urchins/m^2) was creviced bedrock.

(ii) Stubbs Island

Size: There were 52 quadrats that were fully surveyed at Stubbs Island, and 458 green urchins of all sizes that were measured (Table 2). This included 181 (39.5%) legal-sized, 210 (45.9%) sublegal-mature, and 67 (14.6%) sublegal-immature urchins. The analysis of the size

frequency distribution (Table 3 and Fig. 11c) revealed there were three main frequency modes lying at 27 mm (37%), 44 mm (14%), and at 63 mm (48%; $X^2 = 31.7$; df = 36; $p < 0.67$). Although the p-value indicates a non-significant relationship, visual inspection (F_y) clearly reveals three size modes. Mean TD's and weights of urchins at Stubbs Island in November, 2004 were: 66.1 ± 0.5 mm and 91.0 ± 2.0 g for legal-sized urchins; 39.2 ± 0.6 mm and 22.2 ± 0.9 g for sublegal-mature urchins; and 18.3 ± 0.6 mm and 2.5 ± 0.2 g for sublegal-immature urchins (Table 11).

Density: The mean total density for the three transects surveyed at Stubbs Island was 8.81 ± 3.10 urchins/m^2 (Table 12). The mean legal, sublegal-mature and sublegal-immature densities were 3.48 ± 0.95 urchins/m^2, 4.04 ± 1.85 urchins/m^2, and 1.29 ± 0.55 urchins/m^2, respectively (Table 12). As observed in past surveys, the highest mean densities at Stubbs Island occurred at Transect 15. The mean total, legal, and sublegal-mature densities were 12.90 urchins/m^2, 4.45 urchins/m^2, and 7.00 urchins/m^2, respectively (Table 12). The highest mean immature density (2.11 urchins/m^2) occurred at nearby Transect 16. The lowest mean densities for all size categories occurred at Transect 18.

Depth: The density by depth results were slightly different at this site during this survey as compared to what has been commonly observed in the past here and at the Stephenson Islets. Usually the highest mean densities occurred in the shallower depths and the densities gradually decreased with depth. At Stubbs Island in November, 2004, the highest mean total density (14.86 ± 6.63 urchins/m^2) occurred in the shallowest depth range surveyed (0.0 to 0.9 m or 0 to 3 ft above CD) and the densities gradually decreased with depth, but the second highest mean total density (13.00 ± 2.08 urchins/m^2) occurred in the deepest depth range surveyed, 9.4 to 10.1 m (31 to 33 ft) below CD (Table 13c). This was mainly due to the highest mean sublegal density (10.67 urchins/m^2) occurring at this depth. The highest mean legal density (7.57 urchins/m^2) occurred at 0.0 to 0.9 m (0 to 3 ft) above CD.

Substrate: The substrate was recorded for 52 quadrats at Stubbs Island. The substrate most frequently surveyed was smooth bedrock (31 quadrats, Table 14c). The highest mean total (23.00 urchins/m^2), legal (11.00 urchins/m^2) and sublegal (12.00 urchins/m^2) densities all occurred on a substrate of boulders with creviced bedrock (one quadrat only; Table 14c and Fig. 13c). The main substrate with the highest mean total density (17.00 ± 2.39 urchins/m^2) was boulders (Table 14c; 5 quadrats only).

(iii) Plumper Islands

Size: Due to strong winds, the November, 2004 survey was terminated early and only one transect (Transect 23) of 19 quadrats was surveyed in the Plumper Islands. On this one transect there were 174 green urchins observed and measured (Table 2). These urchins consisted of 5 (2.9%) legal-sized urchins, 120 (69.0%) sublegal-mature urchins, and 49 (28.2%) sublegal-immature urchins (Table 2). The size frequency distribution is presented in Fig. 11d, and Table 3 presents the results of the test diameter frequency analysis. There was one main frequency mode occurring at 30 mm ($X^2 = 43.7$; df = 25; $p < 0.0117$). The mean TD's and weights were 61.0 ± 1.9 mm and 79.0 ± 7.3 g for legal-sized urchins, 34.5 ± 0.7 mm and 17.4 ± 1.1 g for sublegal-mature-sized urchins and 19.1 ± 0.5 mm and 3.2 ± 0.2 g for immature-sized urchins (Table 11).

Density: The mean total density in the single transect surveyed at the Plumper Islands was 9.16 urchins/m^2 (Table 12). The mean legal, sublegal-mature and sublegal-immature densities were 0.26, 6.32 and 2.58 urchins/m^2, respectively (Table 12).

Depth: On Transect 23 (the only transect surveyed) there was an extremely high mean total density (51.67 ± 13.45 urchins/m^2) of green urchins in the shallowest depth range (0.0 to 0.6 m or 0 to 2 ft) above CD (Table 13d; Fig. 12d; three quadrats only). This was due mainly to the very high mean density of sublegal-sized green urchins (49.67 urchins/m^2). The highest mean density of legal-sized urchins (2.00 urchins/m^2) also occurred in this depth range. The mean total densities alternately decreased/increased with each lower depth range (Table 13d). However, the mean total and sublegal densities both increased to the second highest levels at the deepest depth range surveyed (9.4 to 10.1 m or 31 to 33 ft below CD). At this depth the mean total density was 17.00 ± 2.89 urchins/m^2 and the mean sublegal density was 16.67 urchins/m^2.

Substrate: There were only 19 quadrats surveyed in the Plumper Islands during this survey, and there were only two substrate types observed, creviced bedrock (17 quadrats) and creviced bedrock with boulders (2 quadrats; Table 14d). The highest mean total density (13.00 urchins/m^2) occurred on creviced bedrock with boulders (Fig. 13d) and consisted entirely of sublegal-sized urchins, whereas the highest mean density of legal-sized urchins (0.29 urchins/m^2) occurred on creviced bedrock (Table 14d). The overall total density of creviced bedrock (19 quadrats) was 9.16 ± 1.86 urchins/m^2.

(iv) Dissection Data

Complete lab measurements were taken from 114 green sea urchins randomly collected from all locations (see sample size 2 in Table 15). An additional 122 green urchins were randomly collected from all locations for test height, test diameter and total wet weight measurements only (see sample size 1 in Table 15). These additional measurements were taken in order to calculate a more accurate test diameter/wet weight relationship, as in the October, 2003 survey. Note that the sample sizes from the Plumper Islands were very small since only one transect was surveyed at this location.

As in most other surveys, lab results indicated that the legal-sized urchins randomly selected from Stubbs Island (n=40) had the largest mean test heights, test diameters and total wet weights, while these same measurements were second largest for urchins from the Stephenson Islets (n=77) and smallest for urchins from the Plumper Islands (n=5; Table 15). The field survey data results agreed with these data, signifying that mean legal test diameters and total wet weights were largest for green urchins measured at Stubbs Island (n=205; Table 11). The field data also showed that the mean test diameters and total wet weights were second largest at the Plumper Islands (but n=6), and smallest for urchins measured at the Stephenson Islets (n=375). Lab measurements for mean drained weights, mean gutted weights, and mean gonad weights were largest for urchins collected from Stubbs Island (n=14; Table 15) and smallest for urchins from the Stephenson Islets (n=32), but the mean stomach content weight was highest at the Plumper Islands (note n=1).

A test for homogeneity of regression slopes showed there was a significant difference between the slopes of the regression lines for the relationship between test diameter and the natural log transformation (to approximate normality) of the total wet weight for the three separate sites (F value = 9.50 with df = 2, 233 and $p < 0.05$). Therefore individual allometric equations ($W=\alpha TD^{\beta}$) were used for each site in the November, 2004 survey when calculating the total wet weight (in grams) from the TD (in millimeters).

The best (i.e., highest R^2) power relationships were calculated between TD (in millimeters) and test heights (in millimeters; Figs. 14 and 15), TD (in millimeters) and total wet weight (in grams; Figs. 16 and 17), and TD (in millimeters) and gonad weight (in grams; Figs. 18 and 19), for all sites combined and for each of the three sites separately, using EXCEL (see figures for equations).

As there was only one legal-sized green urchin from the Plumper Islands sampled for roe quality, it is difficult to make a between-site comparison. This individual urchin had the highest quality roe (i.e., orange/yellow colour and firm texture) and the highest mean roe recovery rate (total gonad weight (all grades) divided by the total drained weight of all urchins sampled; 19.4%; Table 9). 46.9% of urchins sampled from the Stephenson Islets had the highest quality roe but the lowest mean roe recovery rate (17.7%), whereas only 28.6% of the urchins sampled from Stubbs Island had the highest quality roe, but had a higher mean roe recovery rate (19.2%) than the Stephenson Islets (Table 9).

(v) Biomass Estimates

The mean total density at the Stephenson Islets in November, 2004 (9.68 urchins/m^2; Table 12) was extrapolated over the total area between zero and 10 m below CD (485,200 m^2), to determine there was a total of 4,695,594 ± 858,768 green sea urchins of all sizes at this site (Table 16). The total is comprised of 932,726 ± 126,467 legal-sized, 3,178,345 ± 770,214 sublegal-mature-sized, and 584,523 ± 114,051 immature green urchins. The test for homogeneity showed there was a significant difference between the slopes of the TD-total wet weight regressions for the three sites. Therefore the TD-total wet weight relationship derived from the dissection data for urchins collected from the Stephenson Islets only (Fig. 17a) was applied to each individual test measurement recorded in the field for the Stephenson Islets, and mean individual wet weights were calculated for the three size classes. The mean weights per legal-sized, sublegal-mature-sized and immature-sized green sea urchin from Stephenson Islets were determined to be 65.5 ± 0.7 g, 22.6 ± 0.3 g, and 3.2 ± 0.1 g, respectively (Table 11). The individual weights were multiplied with the abundances to give total biomasses of 61.11 ± 8.29 t, 71.79 ± 17.41 t, and 1.87 ± 0.37 t for legal-sized, sublegal-mature and sublegal-immature green sea urchins at Stephenson Islets in November, 2004 (Table 16). The overall total biomass was 134.77 ± 19.29 t.

A total of 172,631 ± 60,790 green urchins was estimated at Stubbs Island by extrapolating the mean densities (Table 12) over the total area. This included 68,223 ± 18,610 legal-sized urchins, 79,154 ± 36,167 sublegal-mature-sized urchins, and 25,254 ± 10,876 sublegal-immature urchins (Table 16). The TD-total wet weight relationship for Stubbs Island urchins was used to calculate the mean individual wet weights (Fig. 17b), which were 91.0 ± 2.0 g for legal-sized, 22.2 ± 0.9 g for sublegal-mature-sized, and 2.5 ± 0.2 g for sublegal-

immature green urchins (Table 11). The biomasses for legal-sized, sublegal-mature-sized, immature-sized, and all urchin size classes combined at Stubbs Island in November, 2004 were 6.21 ± 1.70 t, 1.76 ± 0.81 t, 0.06 ± 0.03 t, and 8.03 ± 1.88 t, respectively (Table 16).

The estimated numbers of green urchins in the Plumper Islands survey site in November, 2004 are based on only one surveyed transect, so the standard errors could not be determined. Based on the limited mean density results (Table 12), there were 58,842 legal-sized urchins, 1,412,211 sublegal-mature urchins, and 576,653 sublegal-immature urchins, for a total of 2,047,705 green urchins (Table 16). Again, the TD-total wet weight relationship for Plumper Island urchins collected from a single transect line was used to calculate the mean individual wet weights (Fig. 17c). These measurements were 79.0 ± 7.3 g, 17.4 ± 1.1 g, and 3.2 ± 0.2 g for legal-sized, sublegal-mature, and sublegal-immature urchins, respectively (Table 11). The biomass estimates were 4.65 t of legal-sized urchins, 24.58 t of sublegal-mature urchins, and 1.86 t of sublegal-immature urchins, for a total biomass estimate of 31.08 t (Table 16).

(c) THE FISHERY

The British Columbia green sea urchin fishery started in 1987, and has had many management restrictions placed on it as it has developed over the years. Restrictions in the number of licenses and of harvesting techniques (hand-picking by divers only), a minimum size limit of 55 mm, Management Area closures, area quotas, Individual Quotas (IQ's), and fishing seasons are all controls that managers have put in place to regulate this fishery. The areas open to commercial fishing during the 2003/2004 and 2004/2005 seasons included Areas 11, 12, 13, 18, 19, and 20 in the South Coast. The quota allowed for Area 12 (where the study area is located) was 224,869 lbs (102.0 t) in both October, 2003 and November, 2004. Table 17 outlines the details of the commercial green sea urchin fishery over the two seasons that these surveys covered. It includes the opening and closing dates for the fishery, the biomass harvested from the Stephenson Islets during the fishing season (as recorded in the harvest logbook records, $B_{fishing}$), and the percentage of harvest that the Stephenson Islets represented of the total harvest from Area 12, and the exploitation of green urchins at the Stephenson Islets. Starting in the 2001/2002 fishing season, the international market began to change, causing a large effect on the B.C. green urchin fishery. There has been an oversupply of green sea urchins on the Japanese market, primarily supplied from Russia, which has caused the global price of green urchins to drop dramatically. The Japanese buyers have not been as interested in buying green urchins from B.C. because they have been able to get an ample supply from Russia for a lower price. The B.C. processors have only been able to sell to Japan when the weather was too rough for the Russian packers to travel (D & D Pacific Fisheries Ltd. 2002). As a result, only 68% of the fishery's total allowable catch (TAC) was harvested in the 2001/2002 fishing season, 80% in 2002/2003, 90% in 2003/2004, and only 44% in the 2004/2005 fishing season (D & D Pacific Fisheries Ltd. 2002, 2003, 2004 and 2005).

(d) FISHING EXPLOITATION

The exploitation of green sea urchins from the Stephenson Islets during each fishing season was calculated using equations 5 and 6 in the Methods Section. Basically, the fishing exploitation represents the amount of legal-sized green sea urchins harvested from the

Stephenson Islets by the fishing industry over the fishing season, divided by the legal-sized biomass just prior to the opening of the fishery. The exploitation at Stephenson Islets was 0.14 ± 0.02 during the 2003/2004 fishing season and 0.12 ± 0.02 during the 2004/2005 fishing season (Table 17).

DISCUSSION

(a) SIZE DISTRIBUTION CHANGES

In a comparison among years, the percentage of legal-sized urchins decreased from October, 2003 to November, 2004 at all three sites. Conversely, the percentages of both the sublegal-mature and immature green urchins increased from October, 2003 to November, 2004, also at all three sites. In addition, the percentages of immature urchins in November, 2004 were the highest of all surveys since 1996 at all three sites. When comparing among sites, the percentage of legal-sized urchins was higher at Stubbs Island in both October, 2003 and November, 2004 than at the other two sites. The contrast in percentages of legal-sized urchins between Stubbs Island and the Stephenson Islets is to be expected because urchins are harvested annually at the latter location but not harvested at Stubbs Island.

The size frequency distributions changed between the different surveys and between the three sites. However, these changes are difficult to analyze and interpret, as test size is not a reliable index of age. Green sea urchins have discontinuous growth, which fluctuates with the availability and species of vegetation (Himmelman *et al.* 1983, Larson *et al.* 1980, Vadas 1977, Vadas *et al.* 2002). A growth study is currently being undertaken at the Pacific Biological Station laboratory, using the growth rings found in cross-sections of the rotules of the Aristotle's Lantern (mouth parts), with the goal of developing a reliable ageing technique. This technique is being validated by studying the growth rings in green urchins of known age to compare with field samples.

(b) LENGTH-WEIGHT RELATIONSHIPS

One would expect that urchins from the Stephenson Islets would be smaller in size in comparison to the other sites as this location has been open to fishing since the commercial green urchin fishery started in 1988. The majority of the larger urchins likely would have been removed from this site over time, thus lowering the mean overall size. One would also expect that urchins at the other two sites, Stubbs Island and the Plumper Islands, would be larger in size as these sites have been closed to commercial fishing for scientific research purposes since 1995. The unfished populations would have been left to continue growing (except for small amounts of "accidental harvesting"; Waddell *et al.* 2003), resulting in a higher abundance of larger urchins, assuming there was low natural mortality. Prior to 1995, the Plumper Islands were open to fishing, whereas Stubbs Island was considered locally as a "reserve", so one would expect that the largest green sea urchins should be observed at Stubbs Island. These expected trends have generally been observed in the surveys conducted since 1996 (see Waddell *et al.* (1997, 2002, 2003) and Waddell and Perry (2005) for data prior to 2003). When comparing between sites, the mean legal-sized TD's for green urchins measured in the field in

the October, 2003 and November, 2004 surveys were largest for urchins from Stubbs Island, second largest for urchins from the Plumper Islands, and smallest for urchins from the Stephenson Islets. In contrast to these results for TD, the pattern among sites was different for weight. The ranking of the sites was the same for the mean legal-sized weights in November, 2004. However, in October, 2003, legal-sized urchins from the Plumper Islands had the highest mean weight, followed by those from Stephenson Islets, then Stubbs Island. The mean legal-sized TD's and the mean weights for urchins at the Stephenson Islets appear to be gradually decreasing over the series of surveys since 1995. In November, 2004, the mean TD's and weights at the Stephenson Islets were the lowest for this site over all the surveys.

The mean sublegal-mature TD's and weights have also decreased at all three sites each survey since October, 2002 (Waddell and Perry 2005). The mean sublegal-mature weights in November, 2004 were the lowest observed of all the surveys at both the Stephenson Islets and Stubbs Island. When comparing between sites, the largest sublegal-mature urchins (mean TD's and weights) were observed at Stephenson Islets, followed by Stubbs Islands and then the Plumper Islands during both the October, 2003 and November, 2004 surveys.

(c) DENSITY

(i) General Changes

The mean density of legal-sized green urchins at Stephenson Islets was the highest for all surveys (since 1995) in October, 2003, but decreased in November, 2004. At Stubbs Island, the mean legal-sized density has been variable but slightly increasing since October, 2002. At the Plumper Islands, the mean legal-sized density increased from 2.34 ± 1.00 urchins/m^2 in October, 2002 to 3.23 ± 1.15 urchins/m^2 in October, 2003, and then it plummeted to 0.26 urchins/m^2 in November, 2004. The standard error could not be calculated during this latter survey at this location as there was only one transect surveyed. This may also account for the very low mean legal-sized density.

The mean sublegal-mature densities increased from the October, 2003 to November, 2004 surveys at all sites. In addition, the mean densities for sublegal-mature green urchins at the Stephenson Islets and the Plumper Islands were the highest in November, 2004 of all the surveys at those locations. The mean densities of immature urchins increased from October, 2002 (Waddell and Perry 2005) to October, 2003 and substantially to November 2004 at all three sites. This suggests there may have been good spawning events and successful recruitment in 2003 and particularly in 2004.

The mean total densities (all size classes combined) for the Stephenson Islets and the Plumper Islands decreased from October, 2002 (Waddell and Perry 2005) to October, 2003, and then increased significantly in November, 2004 to the highest mean total densities for all surveys at both of these locations. Similarly, the mean total density at Stubbs Island decreased from October, 2002 (Waddell and Perry 2005) to October, 2003, and then increased again in November, 2004 to the second highest mean density for this location (the highest mean total density for Stubbs Island occurred in November, 2001).

Among the three sites, the highest mean densities of legal-sized urchins occurred at Stubbs Island in both the October, 2003 and November, 2004 surveys. The mean densities of

sublegal-mature-sized urchins were highest at Stephenson Islets and lowest at Stubbs Island during both surveys. Mean densities of immature urchins were highest at Stubbs Island in October, 2003 and highest at the Plumper Islands in November, 2004.

(ii) Changes with Depth

In general, green sea urchins in this study area have occurred at greater densities in shallower waters during past surveys, and have decreased in density with increasing depth. Himmelman (1986) also observed green urchin abundances generally decreased at greater depths. However, there were subtle differences in depth distributions between the sites and size classes in our surveys. In October, 2003, the depth ranges at which the highest mean densities were observed were consistent with observations made in the November, 1998 to October, 2002 surveys (Waddell and Perry 2005). Green urchins of all sizes at the Stephenson Islets and Stubbs Island generally had the highest mean densities in shallower waters (from 0.6 m above CD to 3.0 m below CD), whereas highest mean densities for the Plumper Islands occurred in deeper waters (between 7.9 to 9.1 m below CD). The observations were different in November, 2004. The highest mean densities were found in the shallowest depth range (from 1.2 m above CD to zero CD) for all size classes at all sites, except for sublegal-sized urchins at Stubbs Island, where the highest mean density occurred at the deepest depth surveyed (9.4 to 10.1 m below CD). Vegetation consumed by green urchins occurs at highest densities in shallower waters. It is unknown why urchins in the Plumper Islands were observed at highest densities in deeper depth intervals in some years. Perhaps the urchins at this site depend more upon drift algae than attached algae.

(iii) Changes with Substrate

The type of substrate at which the highest densities of urchins occurred seemed to vary with survey, site, and size class. Part of these differences in substrate preferences may be due to the fact that different divers were involved in the surveys, and they may have used different criteria for determining between the substrate types, especially between the smooth and creviced bedrock. Also, there were two dive teams for each survey, so again the dive teams may have used different criteria, even though the teams are given guidelines for determining between the substrates. Additionally, as mentioned previously, the transect lines are never repeated exactly between surveys. Regardless, the general trend over all the surveys (since 1995), not surprisingly, was that green sea urchins were observed more consistently and in higher densities on smooth and creviced bedrock, boulders, cobble and shell, less frequently on gravel or pea gravel, and almost never on sand.

(d) DISSECTION RESULTS

The mean stomach weights for legal-sized and sublegal-mature urchins from all three sites in October, 2003 and November, 2004 were average when compared to past surveys (Waddell and Perry 2005). The mean gonad weight for legal-sized urchins was lowest among all surveys at both Stephenson Islets and Stubbs Island in October, 2003. The mean gonad weights for sublegal-mature urchins were lowest for all surveys at the Stephenson Islets and the Plumper Islands in November, 2004 and lowest for all surveys at Stubbs Island in October, 2003.

The quality of roe varies widely each year at the survey sites. Legal-sized green urchins from the Plumper Islands had the highest percentage of the best quality roe (good colour and texture) and highest mean roe recovery rates (the percentage of total gonad weights (regardless of quality) divided by the total drained weight of all urchins collected) in both October, 2003 and November, 2004. In contrast, the sublegal-sized urchins from this location had the lowest values of these same measurements in both surveys.

(e) CHANGES IN BIOMASS

The criterion we used to estimate the "total area" of green sea urchin habitat for the biomass calculations was "all area with a depth between 0 and 10 m below CD". The majority of green urchins are found within this depth range, however, it is realized that they have a wide range in habitable depth, so these are conservative estimates. The area estimates are largest (485,200 m^2) for the Stephenson Islets, so it is not surprising that the biomass estimates are highest for that location. The area estimate for the Plumper Islands (223,600 m^2) is about half the size as for the Stephenson Islets, and the biomass estimates are always smaller. Stubbs Island has the smallest area estimate (19,600 m^2, only 4% of the area of the Stephenson Islets), and always has a much smaller biomass estimate than the other two sites.

During the first three years of surveys there were both pre- and post-fishery surveys conducted, meaning that changes in the total legal biomass could be calculated between the start and finish of a fishing season at the Stephenson Islets (Waddell *et al.* 1997, 2002, 2003). Post-season surveys were eliminated after that due to funding restraints. However, changes in biomass between years can still be calculated. The estimate of total biomass of legal-sized green urchins at the Stephenson Islets site increased from 86.72 ± 14.73 t in October, 2002 (Waddell and Perry 2005) to 106.35 ± 15.52 t in October, 2003 after 6.69 t were removed during the 2002/2003 fishing season. This means the legal biomass actually increased by (106.35 + 6.69 – 86.72 =) 26.32 t over that year, equivalent to a 30% increase. Between October, 2003 and November, 2004, the estimated total legal biomass decreased significantly to 61.11 ± 8.29 t after 15.59 t were removed by the fishery, meaning the biomass estimate actually decreased by (61.17 + 15.59 – 106.35 =) 29.59 t over the year, or 28%.

At Stephenson Islets, the biomass estimate of sublegal-mature green urchins decreased from 76.65 ± 14.75 t in October, 2002 (Waddell and Perry 2005) to 52.36 ± 9.95 t in October, 2003, a decrease of 24.29 t or 32% in one year. The following year (November, 2004), the biomass estimate of sublegal-mature urchins at Stephenson Islets increased by 19.48 t to 71.79 ± 17.41 t, close to the biomass estimate of October, 2002. The biomass estimate of immature urchins at Stephenson Islets increased from 0.29 ± 0.07 t in October, 2002 (Waddell and Perry 2005) to 0.57 ± 0.22 t in October, 2003 to 1.87 ± 0.37 t in November, 2004. This is the largest biomass estimate of immature urchins for the Stephenson Islets since 1996.

The overall total (all sizes combined) biomass estimate for the Stephenson Islets decreased from 163.65 ± 20.85 t in October, 2002 (Waddell and Perry 2005) to 159.27 ± 18.44 t in October, 2003 to 134.77 ± 19.29 t in November, 2004. We have not taken into account the biomass of legal-sized urchins removed by the fishery each year, and this will be discussed further in another paper.

The biomass estimate of legal-sized urchins at Stubbs Island decreased from its high of 9.41 ± 1.86 t in October, 2002 (Waddell and Perry 2005) to 5.02 ± 2.12 t in October, 2003, a 4.39 t or 47% decrease. The legal-sized biomass estimate increased slightly to 6.21 ± 1.70 t in November, 2004. A similar trend was observed for the biomass estimates of sublegal-mature urchins at Stubbs Island. The biomass estimate of immature urchins increased from October, 2002 (Waddell and Perry 2005) to October, 2003, and in November, 2004 was the highest for immature urchins at Stubbs Island of all the surveys.

The biomass estimate of legal-sized urchins in the Plumper Islands increased by 13.66 t from 46.27 ± 19.78 t in October, 2002 (Waddell and Perry 2005) to 59.93 ± 21.33 t in October, 2003 (note the high standard errors). This is the highest legal biomass estimate calculated for the Plumper Islands since surveys began at this location in November, 1996. However, the legal-sized biomass estimate for the Plumper Islands decreased by 55.28 t to 4.65 t in November, 2004. This is not a good estimate as only one transect was completed in this last survey. In contrast, the biomass estimate of sublegal-mature urchins decreased slightly from 12.26 ± 3.58 t in October, 2002 (Waddell and Perry 2005) to 10.30 ± 2.56 t in October, 2003, and then increased to 24.58 t in November, 2004. The biomass estimate of immature urchins increased from the lowest value (0.02 ± 0.02 t) in October, 2002 (Waddell and Perry 2005) to 0.18 ± 0.11 t in October, 2003, to its highest immature biomass (1.86 t) in November, 2004.

In November, 2004, all three sites had the highest biomass estimates for immature green urchins recorded since biomass has been calculated (October, 1995 at Stephenson Islets and November, 1996 at Stubbs Island and the Plumper Islands), suggesting there was a successful spawning event and recruitment in 2004.

(f) FISHING EXPLOITATION

Exploitation is calculated as the proportion of the biomass of legal-sized green urchins harvested by the fishery from the Stephenson Islets to the estimated total biomass of legal-sized urchins at the Stephenson Islets just prior to the opening of the fishery. Analyzing why the exploitation varies between years is difficult because there are many variables influencing this calculation. The total biomass estimates are influenced by the density estimates, which may vary depending on the transects surveyed (not always the same), and by the estimated mean individual weights of the legal-sized green urchins, which also seem to vary between surveys. The amount commercially harvested from the Stephenson Islets during any particular fishing season is influenced not only by the density of legal-sized green urchins available for harvesting, but also by the dynamics of the fishery, such as the supply and demand of the market, the price per pound, directions to the fishers by the processors, fishery management regulations and changes, other fisheries competing for fishers' time, weather, and various other industry-related factors. Currently the amount of green urchins commercially harvested is less influenced by the amount of legal-sized urchins available for harvesting and more influenced by the dynamics of the market. The demand for the product is low due to competition from other countries, therefore the price per pound is low and the fishers choose not to harvest.

The fishing exploitation of legal-sized green urchins at Stephenson Islets increased from 0.08 ± 0.01 during the 2002/03 fishing season to 0.14 ± 0.02 in the 2003/04 fishing

season, and then decreased slightly during the 2004/05 fishing season to 0.12 ± 0.02. The small decrease in the exploitation from the 2003/04 to 2004/05 fishing seasons does not reveal the larger changes in both the biology of the legal-sized green urchins at the Stephenson Islets, and the fishing pressure at this location during these time periods. In actual fact, both the mean densities and mean individual legal-sized weights decreased from October, 2003 to November, 2004 (by 41.9 % and 16.2%, respectively), resulting in a 42.5% decrease in biomass. The amount of green urchins harvested from the Stephenson Islets also decreased, from 14.96 t in the 2003/04 fishing season to 7.25 t in the 2004/05 fishing season, or 51.5%, resulting in only a small change in the exploitation rate. It is interesting to note that despite the fact that the amount harvested from the Stephenson Islets in 2003/04 as compared to 2004/05 decreased by 51.5%, the percentage that the amount of green urchins harvested from the Stephenson Islets represented of the total amount harvested from all of Area 12 increased from 16.51 % in the 2003/04 fishing season to 20.11% in the 2004/05 fishing season.

(g) SAMPLING PROBLEMS

Sampling problems can potentially cause differences between survey results. For instance, it was noted that occasionally the divers started surveying transects deeper than 10.0 m below CD. Since the area estimate for the Stephenson Islets was based on the 10 m isobath, and green urchins are usually sparse at depths below this, the divers' data were truncated to 10 m (33 ft) to calculate the density so that the sampling occurred within the area estimate (however, the original data were used for the size frequency analyses). Second, the divers occasionally neglected to note empty quadrats. This was evident when the recorded depths between the one meter quadrats had a difference of more than 4 ft. "Empty quadrats" were approximately added in, thus reducing the overestimate of density and biomass. Thirdly, due to various reasons (poor weather conditions, strong tidal currents, divers running out of air or having other difficulties, etc.), the divers did not always survey the full length of some of the transects. Since the divers always started at the deep end of the transect and worked their way to the shallow end, the shallower depths were not sampled sufficiently. The density by depth analyses show that densities were generally higher in the shallower depths, especially for the Stephenson Islets and Stubbs Island. Therefore, density and biomass estimates may be underestimated (not as much as October, 2003 and November, 2004 as in past surveys). There was no method available to compensate for the lack of these data.

SUMMARY

The results observed from surveys performed in October, 2003 and November, 2004 indicate that these surveys represent contrasting years. These surveys had variables that often represented extreme values, either high or low, as compared to results observed throughout the whole data series. These results indicate there has possibly been a break in the trends that have been largely seen since the start of the surveys in 1995 and 1996. These differences between the October, 2003 and November, 2004 surveys may be due to a number of factors. These may include: (a) heavy harvesting by the fishery in the Stephenson Islets from November, 2003 to March, 2004, and (b) potentially good settlement leading to strong recruitment events in 2003

and 2004. A more complete comparison over all years of survey data will be presented in a future publication.

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Table 1. Survey dates, vessels involved, and number of transects surveyed at each of the sites, for the October, 2003 and November, 2004 green urchin surveys. (WCGUA = owned by a commercial fisher of the WCGUA, DFO = owned by the DFO).

Survey Dates	Vessels Involved	Number of Transects Surveyed		
		Stephenson Islets	Stubbs Island	Plumper Islands
October 29-31, 2003	Silver Lady (WCGUA) C68 (DFO)	9	3	3
November 2-3, 2004	Second Wind (WCGUA) C68 (DFO)	9	3	1

Table 2. Numbers (N) and percentages (P) of green sea urchins of legal size, sublegal-mature size, sublegal-immature size, unknown size (i.e., counted only), and all sizes (total) for all sites, measured during the October, 2003 and November, 2004 surveys. Note that measuring was incomplete (urchins were measured in most quadrats but only counted in the remainder) for both of these surveys. The numbers in the brackets in the lighter font indicate the actual measured values while the darker font indicates the best estimates (the "unknowns" were proportioned into legal and sublegal values using the ratios from measured data, then added to the original legal and sublegal values, and a zero value was assigned to the unknowns). (M=measured quadrats; T=measured plus counted quadrats; Legal ≥ 55 mm test diameter (TD); Sublegal-mature = 25 mm ≥ TD < 55 mm TD; Sublegal-immature = < 25 mm; Total Number = total number of green sea urchins measured).

Site	Survey Date	No. of Quads	N or P	Number of Legal	Number of Sublegal-mature	Number of Sublegal-immature	Number of Unknown	Total Number
All Sites Combined	Oct. 2003	517 T 326 M	N P	**1,510** (922) **44.2%**(27.0%)	**1,689** (980) **49.5%** (28.7%)	**216** (137) **6.3%** (4.0%)	**0** (1,376) **0%** (40.3%)	**3,415**
	Nov. 2004	496 T 266 M	N P	**1,003** (552) **21.1%**(11.6%)	**3,114** (1,624) **65.6%** (34.2%)	**628** (350) **13.2%** (7.4%)	**0** (2,219) **0%** (46.8%)	**4,745**
Stephenson Islets	Oct. 2003	382 T 195 M	N P	**1,071** (566) **40.4%**(21.4%)	**1,420** (743) **53.6%** (28.1%)	**158** (86) **6.0%** (3.3%)	**0** (1,254) **0%** (47.3%)	**2,649**
	Nov. 2004	425 T 195 M	N P	**817** (366) **19.9%** (8.9%)	**2,784** (1,294) **67.7%** (31.5%)	**512** (234) **12.5%** (5.7%)	**0** (2,219) **0%** (54.0%)	**4,113**
Stubbs Island	Oct. 2003	55 T	N P	**181** (178) **60.1%**(59.1%)	**93**(90) **30.9%** (29.9%)	**27** (26) **9.0%** (8.6%)	**0** (7) **0%** (2.3%)	**301**
	Nov. 2004	52 T	N P	**181** **39.5%**	**210** **45.9%**	**67** **14.6%**	**0** **0%**	**458**
Plumper Islands	Oct. 2003	80 T 76 M	N P	**258** (178) **55.5%**(38.3%)	**176** (147) **37.9%** (31.6%)	**31** (25) **6.7%** (5.4%)	**0** (115) **0%** (24.7%)	**465**
	Nov. 2004	19 T	N P	**5** **2.9%**	**120** **69.0%**	**49** **28.2%**	**0** **0%**	**174**

Table 3. Green sea urchin test diameter frequency distribution analysis for the October, 2003 and November, 2004 surveys. Results were obtained using the analysis software "Mix 3aa" (Macdonald 1994). (Sigma = standard deviation, X^2 = chi-square goodness of fit value, DF = degrees of freedom, P-value = the p-value of the chi-square test).

Site	Survey	Frequency Mode	Mode Mean (mm)	Sigma (mm)	Proportion Of Population	X^2	DF	P-value
All Sites Combined	Oct. 2003	1	6	1.8	0.01	48.0	34	0.0562
		2	32	7.9	0.30			
		3	58	8.8	0.69			
	Nov. 2004	1	41	14.8	1.00	159.1	42	<0.0001
Stephenson Islets	Oct. 2003	1	6	2.5	0.01	48.0	32	0.0347
		2	34	8.8	0.34			
		3	57	7.6	0.64			
	Nov. 2004	1	32	9.7	0.60	51.5	29	0.0061
		2	52	7.7	0.40			
Stubbs Island	Oct. 2003	1	25	5.5	0.20	25.7	31	0.7359
		2	61	10.0	0.80			
	Nov. 2004	1	27	8.7	0.37	31.7	36	0.6741
		2	44	2.8	0.14			
		3	63	8.6	0.48			
Plumper Islands	Oct. 2003	1	32	6.4	0.37	24.0	26	0.5771
		2	62	7.8	0.63			
	Nov. 2004	1	30	10.9	1.00	43.7	25	0.0117

Table 4. Means and standard errors (SE) of test diameters (TD) (using October, 2003 field survey data) and weight (using TD-total wet weight relationships from October, 2003 lab measurements, and applying to field survey data) of legal, sublegal-mature and immature green sea urchins from each of the survey sites. (Legal ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD).

Site	Size	Sample Size	Mean TD (mm)	SE of Mean TD (mm)	Mean Weight (g)	SE of Mean Weight (g)
All Sites Combined	Legal	941	62.9	0.2	84.0	0.8
	Sublegal-Mature	991	41.6	0.3	28.5	0.5
	Sublegal-Immature	137	17.5	0.6	2.9	0.2
Stephenson Islets	Legal	582	61.6	0.2	78.2	0.8
	Sublegal-Mature	751	42.2	0.3	29.0	0.6
	Sublegal-Immature	86	17.4	0.7	2.8	0.2
Stubbs Island	Legal	180	65.5	0.5	77.8	2.1
	Sublegal-Mature	91	41.9	1.1	23.5	1.5
	Sublegal-Immature	26	20.6	0.5	2.5	0.2
Plumper Islands	Legal	179	64.6	0.5	83.1	1.7
	Sublegal-Mature	149	38.0	0.7	20.9	1.1
	Sublegal-Immature	25	14.6	1.5	2.1	0.4

Table 5. Sample mean densities (urchins/m^2) by transect and overall standard errors for green sea urchins of legal size, sublegal-mature size, immature size, unknown size, and all sizes (total) in the October, 2003 survey. (Legal = ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD, Unknown = unmeasured, Total Density = density of all urchins combined. The numbers in the brackets indicate calculations where the unknowns have been proportioned into legal and sublegal values using the ratios from measured data, then added to the original legal and sublegal values, and assigning a zero value to the unknowns. M=measured quadrats; T=total quadrats (measured and counted). Stephenson Islets = Transects 3 to 14, Stubbs Island = Transects 15 to 18, and Plumper Islands = Transects 20 to 23).

Transect Number	Number of Quadrats	Legal Density	Sublegal – Mature Density	Sublegal – Immature Density	Unknown Density	Total Density
3	12 M 23 T	1.57 (3.52)	1.74 (3.91)	0.17 (0.39)	4.35 (0.00)	7.83
5A	19 M 36 T	1.11 (1.81)	1.50 (2.42)	0.14 (0.22)	1.69 (0.00)	4.44
6	25 M 50 T	1.22 (2.46)	1.26 (2.54)	0.06 (0.12)	2.58 (0.00)	5.12
7	27 M 54 T	1.20 (2.63)	1.07 (2.33)	0.06 (0.13)	2.76 (0.00)	5.09
8	16 M 31 T	1.06 (1.77)	1.10 (1.81)	0.19 (0.32)	1.55 (0.00)	3.90
9	25 M 50 T	1.20 (2.74)	2.08 (4.76)	0.08 (0.18)	4.32 (0.00)	7.68
11	20 M 40 T	3.25 (5.25)	2.15 (3.50)	0.30 (0.48)	3.53 (0.00)	9.23
13	23 M 44 T	2.20 (4.14)	4.59 (8.61)	0.84 (1.57)	6.68 (0.00)	14.32
14	28 M 54 T	0.81 (1.41)	1.89 (3.28)	0.22 (0.39)	2.15 (0.00)	5.07
Stephenson Islets Totals or Avg.	195 M 382 T	1.48 ± 0.25 (2.80 ± 0.41)	1.95 ± 0.37 (3.72 ± 0.71)	0.23 ± 0.09 (0.41 ± 0.16)	3.28 ± 0.54 (0.00)	6.93 ± 1.11
15	17 T	1.29 (1.47)	1.29 (1.47)	0.59 (0.65)	0.41 (0.00)	3.59
17	22 T	5.59	2.82	0.73	0.00	9.14
18	16 T	2.06	0.38	0.00	0.00	2.44
Stubbs Island Totals or Avg.	55 T	3.24 ± 1.43 (3.29 ± 1.39)	1.64 ± 0.74 (1.69 ± 0.73)	0.47 ± 0.21 (0.49 ± 0.22)	0.13 ± 0.13 (0.00)	5.47 ± 2.21
20	39 T	3.05 (3.08)	1.62 (1.62)	0.10 (0.10)	0.03 (0.00)	4.79
22	20 M 24 T	2.25 (5.54)	0.83 (2.04)	0.17 (0.42)	4.75 (0.00)	8.00
23	17 T	0.29	3.76	1.00	0.00	5.06
Plumper Islands Totals or Avg.	76 M 80 T	2.23 ± 0.70 (3.23 ± 1.15)	1.84 ± 0.64 (2.20 ± 0.54)	0.31 ± 0.22 (0.39 ± 0.23)	1.44 ± 1.53 (0.00)	5.81 ± 1.03
OVERALL TOTAL	326 M 517 T	1.78 ± 0.29 (2.92 ± 0.36)	1.90 ± 0.29 (3.27 ± 0.55)	0.26 ± 0.07 (0.42 ± 0.12)	2.66 ± 0.51 (0.00)	6.61 ± 0.85

Table 6a. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below CD from all survey sites combined in the October, 2003 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD. The unmeasured urchins have been proportioned into the legal and sublegal estimated values by using the proportions of legal and sublegal urchins in the measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns).

Depth Range (ft)	Depth Range (m)	Number of Quadrats	Legal Density	Sublegal Density	Total Density
-3 to 0	-0.9 to 0.0	49	2.39	2.96	5.35 ± 1.40
1 to 5	0.3 to 1.5	46	6.98	5.30	12.28 ± 2.40
6 to 10	1.8 to 3.0	78	4.97	6.13	11.10 ± 1.40
11 to 15	3.3 to 4.8	73	3.44	3.25	6.68 ± 0.76
16 to 20	4.9 to 6.1	78	3.29	3.03	6.32 ± 0.96
21 to 25	6.4 to 7.6	76	0.80	3.03	3.83 ± 0.51
26 to 30	7.9 to 9.1	95	1.45	2.80	4.25 ± 0.73
31 to 35	9.4 to 10.7	27	1.11	1.96	3.07 ± 0.74

Table 6b. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below CD in the Stephenson Islets in the October, 2003 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD. The unmeasured urchins have been proportioned into the legal and sublegal estimated values by using the proportions of legal and sublegal urchins in the measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns).

Depth Range (ft)	Depth Range (m)	Number of Quadrats	Legal Density	Sublegal Density	Total Density
-3 to 0	-0.9 to 0.0	41	2.44	2.98	5.41 ± 1.64
1 to 5	0.3 to 1.5	32	7.09	6.84	13.94 ± 3.26
6 to 10	1.8 to 3.0	63	5.38	7.22	12.60 ± 1.65
11 to 15	3.3 to 4.8	53	3.70	3.83	7.53 ± 0.89
16 to 20	4.9 to 6.1	54	2.26	3.20	5.46 ± 0.73
21 to 25	6.4 to 7.6	53	0.91	3.81	4.72 ± 0.67
26 to 30	7.9 to 9.1	75	0.77	2.21	2.99 ± 0.43
31 to 35	9.4 to 10.7	15	1.20	2.13	3.33 ± 0.77

Table 6c. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below CD at Stubbs Island in the October, 2003 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD. The unmeasured urchins have been proportioned into the legal and sublegal estimated values by using the proportions of legal and sublegal urchins in the measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns).

Depth Range (ft)	Depth Range (m)	Number Of Quadrats	Legal Density	Sublegal Density	Total Density
-2 to 0	-0.6 to 0.0	4	3.75	4.00	7.75 ± 3.40
1 to 5	0.3 to 1.5	7	9.00	3.00	12.00 ± 4.10
6 to 10	1.8 to 3.0	7	4.14	1.86	6.00 ± 2.36
11 to 15	3.3 to 4.8	10	2.30	1.80	4.10 ± 0.94
16 to 20	4.9 to 6.1	11	4.45	3.82	8.27 ± 3.81
21 to 25	6.4 to 7.6	6	0.33	0.50	0.83 ± 0.31
26 to 30	7.9 to 9.1	6	0.33	1.00	1.33 ± 0.71
31 to 33	9.4 to 10.1	4	0.00	0.50	0.50 ± 0.50

Table 6d. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below CD in the Plumper Islands in the October, 2003 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD. The unmeasured urchins have been proportioned into the legal and sublegal estimated values by using the proportions of legal and sublegal urchins in the measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns).

Depth Range (ft)	Depth Range (m)	Number of Quadrats	Legal Density	Sublegal Density	Total Density
-1 to 0	-0.3 to 0.0	4	0.50	1.75	2.25 ± 1.44
1 to 5	0.3 to 1.5	7	2.14	2.86	5.00 ± 2.04
6 to 10	1.8 to 3.0	8	1.50	2.25	3.75 ± 1.33
11 to 15	3.3 to 4.8	10	2.70	2.10	4.80 ± 2.61
16 to 20	4.9 to 6.1	13	5.38	2.85	8.23 ± 3.80
21 to 25	6.4 to 7.6	17	0.53	1.59	2.12 ± 0.71
26 to 30	7.9 to 9.1	14	6.43	5.86	12.29 ± 3.80
31 to 33	9.4 to 10.1	8	1.50	2.38	3.88 ± 2.00

Table 7a. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type from all survey sites combined in the October, 2003 survey. (Legal ≥ 55 mm TD, Sublegal < 55 mm TD, Unknown = unmeasured, Total Density by Main Substrate = density for all urchins within the dominant substrate type).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
100	Bedrock (smooth)	181	1.50	1.83	2.71	6.04	
120	Bedrock (smooth)/bedrock (crevices)	52	2.92	5.08	4.56	12.56	
123	Bedrock (smooth)/bedrock (crevices)/boulders	1	0.00	0.00	28.00	28.00	
124	Bedrock (smooth)/bedrock (crevices)/cobble	3	1.67	9.33	1.00	12.00	
130	Bedrock (smooth)/boulders	1	6.00	31.00	0.00	37.00	7.01 ± 0.69
134	Bedrock (smooth)/boulders/ cobble	28	0.61	0.57	1.71	2.89	
140	Bedrock (smooth)/cobble	8	1.75	1.25	0.75	3.75	
148	Bedrock (smooth)/cobble/shell	1	0.00	0.00	0.00	0.00	
170	Bedrock (smooth)/sand	1	2.00	1.00	0.00	3.00	
180	Bedrock (smooth)/shell	4	0.00	0.50	0.00	0.50	
200	Bedrock (crevices)	120	2.09	1.88	2.23	6.20	
230	Bedrock (crevices)/boulders	1	0.00	0.00	12.00	12.00	
234	Bedrock (crevices)/boulders/ cobble	1	9.00	11.00	0.00	20.00	6.67 ± 0.56
240	Bedrock (crevices)/cobble	7	4.71	5.43	3.71	13.86	
270	Bedrock (crevices)/sand	1	0.00	1.00	0.00	1.00	
280	Bedrock (crevices)/shell	1	0.00	0.00	0.00	0.00	
300	Boulders	35	1.20	1.71	2.54	5.46	
320	Boulders/bedrock (crevices)	1	8.00	0.00	0.00	8.00	
328	Boulders/bedrock (crevices)/ shell	1	0.00	2.00	0.00	2.00	
340	Boulders/cobble	31	0.97	1.68	2.00	4.65	4.89 ± 0.69
348	Boulders/cobble/shell	3	2.00	0.00	0.00	2.00	
350	Boulders/gravel	1	0.00	0.00	7.00	7.00	
380	Boulders/shell	2	2.00	0.00	0.00	2.00	
400	Cobble	23	2.91	1.57	3.22	7.70	
420	Cobble/bedrock (creviced)	1	0.00	2.00	0.00	2.00	
430	Cobble/boulders	4	1.25	0.50	3.50	5.25	6.94 ± 1.64
432	Cobble/boulders/bedrock (crevices)	1	0.00	0.00	10.00	10.00	
450	Cobble/gravel	2	0.00	1.50	1.00	2.50	
730	Sand/boulders	1	0.00	0.00	0.00	0.00	0.00

Table 7b. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type in the Stephenson Islets in the October, 2003 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD, Unknown = unmeasured, Total Density by Main Substrate = density for all urchins within the dominant substrate type).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
100	Bedrock (smooth)	133	0.80	1.73	3.68	6.21	7.69 ± 0.91
120	Bedrock (smooth)/bedrock (crevices)	25	3.16	5.80	9.48	18.44	
123	Bedrock (smooth)/bedrock (crevices)/boulders	1	0.00	0.00	28.00	28.00	
124	Bedrock (smooth)/bedrock (crevices)/cobble	2	2.00	12.50	1.50	16.00	
130	Bedrock (smooth)/boulders	1	6.00	31.00	0.00	37.00	
134	Bedrock (smooth)/boulders/ cobble	28	0.61	0.57	1.71	2.89	
140	Bedrock (smooth)/cobble	3	3.33	2.33	2.00	7.67	
170	Bedrock (smooth)/sand	1	2.00	1.00	0.00	3.00	
200	Bedrock (crevices)	107	2.11	2.00	2.11	6.22	6.80 ± 0.51
230	Bedrock (crevices)/boulders	1	0.00	0.00	12.00	12.00	
234	Bedrock (crevices)/boulders/ cobble	1	9.00	11.00	0.00	20.00	
240	Bedrock (crevices)/cobble	7	4.71	5.43	3.71	13.86	
270	Bedrock (crevices)/sand	1	0.00	1.00	0.00	1.00	
300	Boulders	27	1.22	1.52	3.07	5.81	5.16 ± 0.74
340	Boulders/cobble	30	0.77	1.67	2.07	4.50	
350	Boulders/gravel	1	0.00	0.00	7.00	7.00	
400	Cobble	4	3.25	3.00	0.00	6.25	5.25 ± 1.62
420	Cobble/bedrock (crevices)	1	0.00	2.00	0.00	2.00	
430	Cobble/boulders	4	1.25	0.50	3.50	5.25	
432	Cobble/boulders/bedrock (crevices)	1	0.00	0.00	10.00	10.00	
450	Cobble/gravel	2	0.00	1.50	1.00	2.50	
730	Sand/boulders	1	0.00	0.00	0.00	0.00	0.00

Table 7c. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type at Stubbs Island in the October, 2003 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD, Unknown = unmeasured, Total Density by Main Substrate = density for all urchins within the dominant substrate type).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
100	Bedrock (smooth)	20	2.40	2.05	0.00	4.45	6.18 ± 1.47
120	Bedrock (smooth)/bedrock (crevices)	10	6.80	3.80	0.00	10.60	
124	Bedrock (smooth)/bedrock (crevices)/cobble	1	1.00	3.00	0.00	4.00	
140	Bedrock (smooth)/cobble	1	3.00	2.00	0.00	5.00	
148	Bedrock (smooth)/cobble/ shell	1	0.00	0.00	0.00	0.00	
200	Bedrock (crevices)	8	3.13	1.50	0.13	4.75	4.22 ± 2.76
280	Bedrock (crevices)/shell	1	0.00	0.00	0.00	0.00	
300	Boulders	5	1.60	3.20	1.20	6.00	4.54 ± 2.10
320	Boulders/bedrock (crevices)	1	8.00	0.00	0.00	8.00	
328	Boulders/bedrock (crevices)/ shell	1	0.00	2.00	0.00	2.00	
340	Boulders/cobble	1	7.00	2.00	0.00	9.00	
348	Boulders/cobble/shell	3	2.00	0.00	0.00	2.00	
380	Boulders/shell	2	2.00	0.00	0.00	2.00	

Table 7d. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type in the Plumper Islands in the October, 2003 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD, Unknown = unmeasured, Total Density by Main Substrate = density for all urchins within the dominant substrate type).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
100	Bedrock (smooth)	28	4.18	2.18	0.04	6.39	5.08 ± 1.14
120	Bedrock (smooth)/bedrock (crevices)	17	0.29	4.76	0.00	5.06	
140	Bedrock (smooth)/cobble	4	0.25	0.25	0.00	0.50	
180	Bedrock (smooth)/shell	4	0.00	0.50	0.00	0.50	
200	Bedrock (crevices)	5	0.00	0.00	8.00	8.00	8.00 ± 8.00
300	Boulders	3	0.33	1.00	0.00	1.33	1.33 ± 0.33
400	Cobble	19	2.84	1.26	3.89	8.00	8.00 ± 2.49

Table 8. Summary results of measurements taken during green urchin dissections in the October, 2003 survey. (Legal ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD. SE = Standard Error; Gutted Weight = stomach and contents removed; Gonad Texture: 0=unknown or no sample, 1=orange/yellow, 2=yellow with other colours, 3=brown/red; Gonad Texture: 0=unknown or no sample, 1=firm, 2=semi-firm, 3=flimsy; Sex: 1=male, 2=female, 3=juvenile or unknown. Sample Size 1 is for test height, TD and total wet weight. Sample Size 2 is for all other calculations).

Summary Information			LOCATION								
			STEPHENSON ISLETS			STUBBS ISLAND			PLUMPER ISLANDS		
			Legal	Sublegal-mature	Sublegal-immature	Legal	Sublegal-mature	Sublegal-immature	Legal	Sublegal-mature	Sublegal-immature
Sample Size 1			86	73	10	43	15	0	34	23	2
Mean Test Height (mm) ± SE			31.0 (± 0.3)	22.1 (± 0.6)	12.4 (± 0.7)	37.1 (± 0.8)	22.8 (± 1.6)	0	34.6 (± 0.7)	19.5 (± 1.0)	12.5 (± 0.5)
Mean Test Diameter (mm) ± SE			60.5 (± 0.5)	43.1 (± 1.0)	22.1 (± 0.7)	68.8 (± 1.2)	41.7 (± 2.4)	0	66.2 (± 1.2)	37.7 (± 1.5)	23.5 (± 0.5)
Mean Total Wet Weight (g) ± SE			78.1 (± 1.7)	32.2 (± 1.9)	4.6 (± 0.4)	103.4 (± 6.1)	26.0 (± 4.3)	0	95.1 (± 4.9)	21.2 (± 2.4)	5.2 (± 0.2)
Sample Size 2			32	44	6	15	11	0	14	12	2
Mean Drained Weight (g) ± SE			61.5 (± 2.2)	22.9 (± 1.7)	4.2 (± 0.5)	74.7 (± 6.6)	17.5 (± 3.6)	0	71.0 (± 5.3)	17.9 (± 2.8)	5.2 (± 0.3)
Mean Gutted Weight (g) ± SE			43.7 (± 1.8)	16.4 (± 1.3)	2.9 (± 0.3)	55.2 (± 5.0)	12.9 (± 2.7)	0	51.1 (± 3.4)	12.5 (± 2.1)	3.5 (± 0.2)
Mean Stomach and Contents Weight (g) ± SE			17.8 (± 0.8)	6.6 (± 0.6)	1.3 (± 0.2)	19.5 (± 2.1)	4.7 (± 0.9)	0	19.9 (± 2.3)	5.5 (± 0.8)	1.7 (± 0.1)
Sex	% Male		47	27	0	40	0	0	29	25	0
	% Female		53	52	0	53	55	0	71	33	0
	% Unknown		0	21	100	7	45	0	0	42	100
Gonad	Mean Weight (g) ± SE		9.6 (± 1.0)	2.9 (± 0.4)	0	13.9 (± 2.3)	2.2 (± 0.9)	0	14.3 (± 1.0)	2.0 (± 0.7)	0.1 (± 0.1)
	Colour Proportion	0	0	0.02	1.00	0	0.09	0	0	0	0.50
		1	0.56	0.75	0	0.27	0.91	0	0.57	0.92	0.50
		2	0.25	0.07	0	0.47	0	0	0.21	0	0
		3	0.06	0.05	0	0.13	0	0	0	0	0
		4	0.13	0.11	0	0.13	0	0	0.21	0.08	0
	Texture Proportion	0	0	0.02	1.00	0	0.09	0	0	0	0.50
		1	0.59	0.25	0	0.67	0.27	0	0.79	0.17	0
		2	0.34	0.66	0	0.33	0.64	0	0.21	0.83	0.50
		3	0.06	0.07	0	0	0	0	0	0	0

Table 9. Comparisons of percentage of highest roe quality (roe with best colour and texture) and mean roe recovery rates (total gonad weight divided by total drained weight) between the October, 2003 and November, 2004 surveys at Stephenson Islets, Stubbs Island and Plumper Islands). (Sample size = total number of urchins with roe).

Location	Sample Size		Highest Quality Roe		Mean Roe Recovery Rates	
	Legal	Sublegal	Legal	Sublegal	Legal	Sublegal
Stephenson Islets						
October, 2003	32	43	37.5%	23.3%	15.6%	12.6%
November, 2004	32	41	46.9%	58.5%	17.7%	11.1%
Stubbs Island						
October, 2003	13	12	23.1%	33.3%	19.0%	13.1%
November, 2004	14	9	28.6%	33.3%	19.2%	11.3%
Plumper Islands						
October, 2003	14	13	50.0%	7.7%	20.1%	10.9%
November, 2004	1	6	100.0%	0.0%	19.4%	9.0%

Table 10. Calculated total abundance (number) and biomass (tonnes) of green sea urchins by site and size category in October, 2003 (incorporates estimates from unknowns). (Legal ≥ 55 mm test diameter (TD), Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD. Biomass estimates were calculated using TD-weight relationships determined from October, 2003 lab measurements for each of the three sites separately, and applied to the field survey TD measurements).

Size Category	Stephenson Islets	Stubbs Island	Plumper Islands
Number of Legal-sized	1,360,338 ± 198,340	64,502 ± 27,272	721,110 ± 256,332
Number of Sublegal-mature	1,803,623 ± 342,261	33,142 ± 14,293	491,920 ± 120,631
Number of Sublegal-immature	200,685 ± 76,582	9,622 ± 4,271	86,645 ± 52,185
Number of all sizes	3,364,646 ± 540,287	107,265 ± 43,385	1,299,675 ± 229,518
Biomass of Legal-size (t)	106.35 ± 15.52	5.02 ± 2.12	59.93 ± 21.33
Biomass of Sublegal-mature (t)	52.36 ± 9.95	0.78 ± 0.34	10.30 ± 2.56
Biomass of Sublegal-immature (t)	0.57 ± 0.22	0.02 ± 0.01	0.18 ± 0.11
Total Biomass (t)	159.27 ± 18.44	5.82 ± 2.15	70.41 ± 21.48

Table 11. Means and standard errors (SE) of test diameters (TD) (using November, 2004 field survey data) and weight (using TD-total wet weight relationships from November, 2004 lab measurements, and applying to field survey data) of legal, sublegal-mature and immature green sea urchins from each of the survey sites. (Legal ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD).

Site	Size	Sample Size	Mean TD (mm)	SE of Mean TD (mm)	Mean Weight (g)	SE of Mean Weight (g)
All Sites Combined	Legal	585	62.0	0.2	84.3	1.1
	Sublegal-Mature	1,746	39.1	0.2	25.0	0.3
	Sublegal-Immature	364	19.3	0.2	3.4	0.1
Stephenson Islets	Legal	375	59.9	0.2	65.5	0.7
	Sublegal-Mature	1,401	39.5	0.2	22.6	0.3
	Sublegal-Immature	247	19.6	0.3	3.2	0.1
Stubbs Island	Legal	205	66.1	0.5	91.0	2.0
	Sublegal-Mature	225	39.2	0.6	22.2	0.9
	Sublegal-Immature	68	18.3	0.6	2.5	0.2
Plumper Islands (Transect 23 only)	Legal	6	61.0	1.9	79.0	7.3
	Sublegal-Mature	120	34.5	0.7	17.4	1.1
	Sublegal-Immature	49	19.1	0.5	3.2	0.2

Table 12. Sample mean densities (urchins/m^2) by transect and overall standard errors for green sea urchins of legal size, sublegal-mature size, immature size, unknown size, and all sizes (total) in the November, 2004 survey. (Legal = ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD, Unknown = unmeasured, Total Density = density of all urchins combined. The numbers in the brackets indicate calculations where the unknowns have been proportioned into legal and sublegal values using the ratios from measured data, then added to the original legal and sublegal values, and assigning a zero value to the unknowns. M=measured quadrats; T=total quadrats (measured and counted). Stephenson Islets = Transects 3 to 14, Stubbs Island = Transects 15 to 18, and Plumper Islands = Transect 23).

Transect Number	Number of Quadrats	Legal Density	Sublegal – Mature Density	Sublegal – Immature Density	Unknown Density	Total Density
3	7 M 20 T	0.55 (1.85)	0.70 (2.35)	0.65 (2.20)	4.50 (0.00)	6.40
5A	25 M 50 T	1.12 (2.24)	1.10 (2.18)	0.24 (0.48)	2.44 (0.00)	4.90
6	15 M 30 T	0.97 (1.70)	3.83 (6.73)	0.50 (0.87)	4.00 (0.00)	9.30
7	39 M 77 T	0.78 (1.61)	2.55 (5.27)	0.22 (0.45)	3.79 (0.00)	7.34
8	8 M 16 T	1.38 (3.44)	1.19 (2.94)	0.44 (1.06)	4.44 (0.00)	7.44
9	31 M 73 T	0.92 (2.18)	5.97 (14.14)	0.75 (1.78)	10.45 (0.00)	18.10
11	21 M 61 T	1.11 (3.00)	2.18 (5.87)	0.46 (1.23)	6.34 (0.00)	10.10
13	18 M 35 T	0.63 (1.06)	5.29 (9.00)	0.69 (1.17)	4.63 (0.00)	11.23
14	31 M 63 T	0.49 (0.94)	2.24 (4.25)	1.00 (1.90)	3.37 (0.00)	7.10
Stephenson Islets Totals or Avg.	195 M 425 T	0.86 ± 0.09 (1.92 ± 0.26)	3.04 ± 0.67 (6.55 ± 1.59)	0.55 ± 0.11 (1.20 ± 0.24)	5.22 ± 1.11 (0.00)	9.68 ± 1.77
15	20 T	4.45	7.00	1.45	0.00	12.90
16	18 T	4.22	3.56	2.11	0.00	9.89
18	14 T	1.14	0.43	0.00	0.00	1.57
Stubbs Island Totals or Avg.	52 T	3.48 ± 0.95	4.04 ± 1.85	1.29 ± 0.55	0.00	8.81 ± 3.10
23	19 T	0.26	6.32	2.58	0.00	9.16
Plumper Islands Totals or Avg.	19 T	0.26	6.32	2.58	0.00	9.16
OVERALL TOTAL	266 M 496 T	1.11 ± 0.22 (2.02 ± 0.27)	3.27 ± 0.60 (6.28 ± 1.36)	0.71 ± 0.15 (1.27 ± 0.21)	4.47 ± 1.04 (0.00)	9.57 ± 1.52

Table 13a. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below CD from all survey sites combined in the November, 2004 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD. The unmeasured urchins have been proportioned into the legal and sublegal estimated values by using the proportions of legal and sublegal urchins in the measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns).

Depth Range (ft)	Depth Range (m)	Number of Quadrats	Legal Density	Sublegal Density	Total Density
-4 to 0	-1.2 to 0.0	27	7.74	22.19	29.93 ± 4.12
1 to 5	0.3 to 1.5	62	4.63	12.40	17.03 ± 1.38
6 to 10	1.8 to 3.0	85	3.73	8.99	12.72 ± 0.89
11 to 15	3.3 to 4.8	72	2.39	7.51	9.90 ± 1.16
16 to 20	4.9 to 6.1	76	1.36	7.13	8.49 ± 1.04
21 to 25	6.4 to 7.6	86	0.70	4.23	4.93 ± 0.50
26 to 30	7.9 to 9.1	78	0.53	4.44	4.96 ± 0.57
31 to 35	9.4 to 10.7	26	0.54	5.62	6.15 ± 1.20
36	11.0	4	0.00	6.00	6.00 ± 2.74

Table 13b. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below CD in the Stephenson Islets in the November, 2004 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD. The unmeasured urchins have been proportioned into the legal and sublegal estimated values by using the proportions of legal and sublegal urchins in the measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns).

Depth Range (ft)	Depth Range (m)	Number of Quadrats	Legal Density	Sublegal Density	Total Density
-4 to 0	-1.2 to 0.0	17	5.41	26.94	32.29 ± 4.66
1 to 5	0.3 to 1.5	51	4.35	13.78	18.14 ± 1.57
6 to 10	1.8 to 3.0	77	3.49	9.36	12.86 ± 0.94
11 to 15	3.3 to 4.8	63	1.83	8.22	10.05 ± 1.28
16 to 20	4.9 to 6.1	67	1.19	7.64	8.84 ± 1.15
21 to 25	6.4 to 7.6	77	0.61	4.39	5.00 ± 0.53
26 to 30	7.9 to 9.1	63	0.62	4.59	5.21 ± 0.66
31 to 35	9.4 to 10.7	20	0.30	3.20	3.50 ± 0.76
36	11.0	4	0.00	6.00	6.00 ± 2.74

Table 13c. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below CD at Stubbs Island in the November, 2004 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD. The unmeasured urchins have been proportioned into the legal and sublegal estimated values by using the proportions of legal and sublegal urchins in the measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns).

Depth Range (ft)	Depth Range (m)	Number Of Quadrats	Legal Density	Sublegal Density	Total Density
-3 to 0	-0.9 to 0.0	7	7.57	7.29	14.86 ± 6.63
1 to 5	0.3 to 1.5	8	6.13	6.75	12.88 ± 2.76
6 to 10	1.8 to 3.0	6	5.50	5.17	10.67 ± 3.50
11 to 15	3.3 to 4.8	7	4.86	5.43	10.29 ± 2.78
16 to 20	4.9 to 6.1	7	2.29	3.86	6.14 ± 2.66
21 to 25	6.4 to 7.6	7	1.29	3.71	5.00 ± 2.07
26 to 30	7.9 to 9.1	11	0.36	3.09	3.45 ± 1.06
31 to 33	9.4 to 10.1	3	2.33	10.67	13.00 ± 2.08

Table 13d. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below CD in the Plumper Islands in the November, 2004 survey). (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD. The unmeasured urchins have been proportioned into the legal and sublegal estimated values by using the proportions of legal and sublegal urchins in the measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns).

Depth Range (ft)	Depth Range (m)	Number of Quadrats	Legal Density	Sublegal Density	Total Density
-2 to 0	-0.6 to 0.0	3	2.00	49.67	51.67±13.45
1 to 5	0.3 to 1.5	3	0.00	9.33	9.33 ± 4.33
6 to 10	1.8 to 3.0	2	0.50	13.00	13.50 ± 9.50
11 to 15	3.3 to 4.8	2	1.00	3.00	4.00 ± 3.00
16 to 20	4.9 to 6.1	2	0.00	5.00	5.00 ± 1.00
21 to 25	6.4 to 7.6	2	0.00	2.00	2.00 ± 2.00
26 to 30	7.9 to 9.1	4	0.00	5.25	5.25 ± 2.66
31 to 33	9.4 to 10.1	3	0.33	16.67	17.00 ± 2.89

Table 14a. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type from all survey sites combined in the November, 2004 survey. (Legal ≥ 55 mm TD, Sublegal < 55 mm TD, Unknown = unmeasured, Total Density by Main Substrate = density for all urchins within the dominant substrate type).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
100	Bedrock (smooth)	210	1.19	3.59	4.57	9.34	8.92 ± 0.63
120	Bedrock (smooth)/bedrock (crevices)	1	0.00	0.00	1.00	1.00	
130	Bedrock (smooth)/boulders	4	0.25	2.50	2.50	5.25	
134	Bedrock (smooth)/boulders/ cobble	2	0.00	0.00	5.50	5.50	
140	Bedrock (smooth)/cobble	17	0.29	2.29	2.88	5.47	
145	Bedrock (smooth)/cobble/ gravel	2	2.00	4.50	9.00	15.50	
170	Bedrock (smooth)/sand	1	0.00	1.00	0.00	1.00	
180	Bedrock (smooth)/shell	1	0.00	3.00	0.00	3.00	
200	Bedrock (crevices)	119	1.26	5.32	5.96	12.54	11.36 ± 0.73
230	Bedrock (crevices)/boulders	3	0.00	9.00	0.00	9.00	
234	Bedrock (crevices)/boulders/ cobble	1	1.00	0.00	0.00	1.00	
240	Bedrock (crevices)/cobble	29	1.24	4.52	4.14	9.90	
248	Bedrock (crevices)/cobble/ shell	4	0.50	3.00	1.25	4.75	
250	Bedrock (crevices)/gravel	3	0.33	0.33	7.33	8.00	
258	Bedrock (crevices)/gravel/ shell	1	2.00	17.00	0.00	19.00	
268	Bedrock (crevices)/pea gravel/shell	2	0.00	5.00	6.00	11.00	
280	Bedrock (crevices)/shell	15	0.80	3.80	3.40	8.00	
300	Boulders	5	1.40	3.60	2.40	7.40	9.19 ± 1.17
310	Boulders/bedrock (smooth)	1	0.00	0.00	10.00	10.00	
320	Boulders/bedrock (creviced)	1	11.00	12.00	0.00	23.00	
340	Boulders/cobble	6	6.00	9.33	0.00	15.33	
345	Boulders/cobble/gravel	7	1.86	6.57	7.14	15.57	
347	Boulders/cobble/sand	6	0.67	2.50	2.67	5.83	
348	Boulders/cobble/shell	3	0.00	3.00	7.00	10.00	
354	Boulders/gravel/cobble	1	0.00	1.00	0.00	1.00	
357	Boulders/gravel/sand	4	0.00	0.25	0.25	0.50	
358	Boulders/gravel/shell	2	0.00	0.50	0.00	0.50	
381	Boulders/shell/bedrock (smooth)	1	0.00	0.00	0.00	0.00	

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Table 14a. continued from previous page.

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
400	Cobble	7	0.14	1.57	7.57	9.29	
410	Cobble/bedrock (smooth)	1	0.00	0.00	3.00	3.00	
430	Cobble/boulders	4	0.25	8.00	1.50	9.75	
437	Cobble/boulders/sand	1	0.00	0.00	4.00	4.00	
450	Cobble/gravel	6	0.50	2.00	2.00	4.50	7.03 ± 1.14
457	Cobble/gravel/sand	11	0.00	3.36	2.73	6.09	
470	Cobble/sand	3	2.67	3.67	2.67	9.00	
480	Cobble/shell	1	0.00	0.00	14.00	14.00	
482	Cobble/shell/bedrock (creviced)	1	0.00	0.00	0.00	0.00	
540	Gravel/cobble	3	0.33	1.00	0.00	1.33	
567	Gravel/pea gravel/sand	1	0.00	0.00	4.00	4.00	3.20 ± 1.39
572	Gravel/sand/bedrock (creviced)	1	2.00	6.00	0.00	8.00	
673	Pea gravel/sand/boulders	3	0.33	0.00	1.67	2.00	
682	Pea gravel/shell/bedrock (creviced)	1	0.00	0.00	3.00	3.00	2.25 ± 1.11

Table 14b. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type in the Stephenson Islets in the November, 2004 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD, Unknown = unmeasured, Total Density by Main Substrate = density for all urchins within the dominant substrate type).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
100	Bedrock (smooth)	179	0.88	3.60	5.36	9.84	9.29 ± 0.68
120	Bedrock (smooth)/bedrock (crevices)	1	0.00	0.00	1.00	1.00	
130	Bedrock (smooth)/boulders	4	0.25	2.50	2.50	5.25	
134	Bedrock (smooth)/boulders/ cobble	2	0.00	0.00	5.50	5.50	
140	Bedrock (smooth)/cobble	17	0.29	2.29	2.88	5.47	
145	Bedrock (smooth)/cobble/ gravel	2	2.00	4.50	9.00	15.50	
170	Bedrock (smooth)/sand	1	0.00	1.00	0.00	1.00	
180	Bedrock (smooth)/shell	1	0.00	3.00	0.00	3.00	
200	Bedrock (crevices)	98	1.24	4.69	7.23	13.17	11.64 ± 0.84
230	Bedrock (crevices)/boulders	1	0.00	1.00	0.00	1.00	
234	Bedrock (crevices)/boulders/ cobble	1	1.00	0.00	0.00	1.00	
240	Bedrock (crevices)/cobble	19	0.21	2.37	6.32	8.89	
248	Bedrock (crevices)/cobble/ shell	4	0.50	3.00	1.25	4.75	
250	Bedrock (crevices)/gravel	2	0.00	0.00	11.00	11.00	
258	Bedrock (crevices)/gravel/ shell	1	2.00	17.00	0.00	19.00	
268	Bedrock (crevices)/pea gravel/shell	2	0.00	5.00	6.00	11.00	
280	Bedrock (crevices)/shell	15	0.80	3.80	3.40	8.00	
300	Boulders	5	1.40	3.60	2.40	7.40	7.97 ± 1.17
310	Boulders/bedrock (smooth)	1	0.00	0.00	10.00	10.00	
340	Boulders/cobble	2	7.00	8.00	0.00	15.00	
345	Boulders/cobble/gravel	7	1.86	6.57	7.14	15.57	
347	Boulders/cobble/sand	6	0.67	2.50	2.67	5.83	
348	Boulders/cobble/shell	3	0.00	3.00	7.00	10.00	
354	Boulders/gravel/cobble	1	0.00	1.00	0.00	1.00	
357	Boulders/gravel/sand	4	0.00	0.25	0.25	0.50	
358	Boulders/gravel/shell	2	0.00	0.50	0.00	0.50	
381	Boulders/shell/bedrock (smooth)	1	0.00	0.00	0.00	0.00	

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Table 14b. continued from previous page.

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
400	Cobble	6	0.17	1.83	8.83	10.83	
410	Cobble/bedrock (smooth)	1	0.00	0.00	3.00	3.00	
430	Cobble/boulders	4	0.25	8.00	1.50	9.75	
437	Cobble/boulders/sand	1	0.00	0.00	4.00	4.00	
450	Cobble/gravel	6	0.50	2.00	2.00	4.50	7.24 ± 1.16
457	Cobble/gravel/sand	11	0.00	3.36	2.73	6.09	
470	Cobble/sand	3	2.67	3.67	2.67	9.00	
480	Cobble/shell	1	0.00	0.00	14.00	14.00	
482	Cobble/shell/bedrock (creviced)	1	0.00	0.00	0.00	0.00	
540	Gravel/cobble	3	0.33	1.00	0.00	1.33	
567	Gravel/pea gravel/sand	1	0.00	0.00	4.00	4.00	3.20 ± 1.39
572	Gravel/sand/bedrock (creviced)	1	2.00	6.00	0.00	8.00	
673	Pea gravel/sand/boulders	3	0.33	0.00	1.67	2.00	
682	Pea gravel/shell/bedrock (creviced)	1	0.00	0.00	3.00	3.00	2.25 ± 1.11

Table 14c. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type at Stubbs Island in the November, 2004 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD, Unknown = unmeasured, Total Density by Main Substrate = density for all urchins within the dominant substrate type).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
100	Bedrock (smooth)	31	2.97	3.48	0.00	6.45	6.45 ± 1.72
200	Bedrock (crevices)	4	5.75	7.50	0.00	13.25	11.53 ± 1.62
240	Bedrock (crevices)/cobble	10	3.20	8.60	0.00	11.80	
250	Bedrock (crevices)/gravel	1	1.00	1.00	0.00	2.00	
320	Boulders/bedrock (crevices)	1	11.00	12.00	0.00	23.00	17.00 ± 2.39
340	Boulders/cobble	4	5.50	10.00	0.00	15.50	
400	Cobble	1	0.00	0.00	0.00	0.00	0.00

Table 14d. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type in the Plumper Islands in the November, 2004 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD, Unknown = unmeasured, Total Density by Main Substrate = density for all urchins within the dominant substrate type).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
200	Bedrock (crevices)	17	0.29	8.41	0.00	8.71	9.16 ± 1.86
230	Bedrock (crevices)/boulders	2	0.00	13.00	0.00	13.00	

Table 15. Summary results of measurements taken during green urchin dissections from the November, 2004 survey. (Legal ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD. SE = Standard Error; Gutted Weight = stomach contents removed; Gonad Texture: 0=unknown or no sample, 1=orange/yellow, 2=yellow with other colours, 3=brown/red; Gonad Texture: 0=unknown or no sample, 1=firm, 2=semi-firm, 3=flimsy; Sex: 1=male, 2=female, 3=juvenile or unknown. Sample Size 1 is for test height, TD and total wet weight. Sample Size 2 is for all other calculations).

Summary Information			LOCATION								
			STEPHENSON ISLETS			STUBBS ISLAND			PLUMPER ISLANDS		
			Legal	Sublegal-mature	Sublegal-mmature	Legal	Sublegal-mature	Sublegal-immature	Legal	Sublegal-mature	Sublegal-immature
Sample Size 1			77	80	5	40	15	0	5	14	0
Mean Test Height (mm) ± SE			32.7 (± 0.4)	21.8 (± 0.6)	10.0 (± 0.9)	37.2 (± 0.9)	23.4 (± 1.5)	0	30.6 (± 1.3)	21.5 (± 1.3)	0
Mean Test Diameter (mm) ± SE			62.2 (± 0.7)	42.2 (± 0.9)	19.8 (± 2.4)	67.9 (± 1.3)	42.8 (± 2.3)	0	60.0 (± 2.4)	42.7 (± 2.7)	0
Mean Total Wet Weight (g) ± SE			79.1 (± 2.7)	27.7 (± 1.5)	3.4 (± 0.8)	108.7 (± 5.7)	29.7 (± 3.5)	0	77.7 (± 7.9)	31.6 (± 4.7)	0
Sample Size 2			32	45	4	14	10	0	1	8	0
Mean Drained Weight (g) ± SE			62.3 (± 3.5)	19.9 (± 1.5)	2.8 (± 0.9)	79.5 (± 6.0)	23.0 (± 3.3)	0	74.4	17.4 (± 3.9)	0
Mean Gutted Weight (g) ± SE			47.4 (± 2.9)	14.0 (± 1.1)	2.1 (± 0.7)	59.4 (± 5.3)	16.8 (± 2.5)	0	51.8	12.0 (± 2.8)	0
Mean Stomach and Contents Weight (g) ± SE			14.9 (± 1.0)	5.8 (± 0.4)	0.7 (± 0.2)	20.1 (± 1.4)	6.2 (± 0.9)	0	22.6	5.4 (± 1.1)	0
Sex	% Male		50	11	0	50	50	0	100	13	0
	% Female		47	42	0	43	10	0	0	0	0
	% Unknown		3	47	100	7	40	0	0	87	0
Gonad	Mean Weight (g) ± SE		11.0 (± 1.0)	2.1 (± 0.3)	0	15.3 (± 2.0)	2.5 (±0.6)	0	14.4	1.4 (± 0.5)	0
	Colour Proportion	0	0	0.09	1.00	0	0.10	0	0	0.25	0
		1	0.59	0.84	0	0.36	0.80	0	1.00	0.75	0
		2	0.41	0	0	0.50	0.10	0	0	0	0
		3	0	0.02	0	0.07	0	0	0	0	0
		4	0	0.04	0	0.07	0	0	0	0	0
	Texture Proportion	0	0	0.09	1.00	0	0.10	0	0	0.25	0
		1	0.81	0.58	0	0.64	0.30	0	1.00	0	0
		2	0.19	0.27	0	0.36	0.60	0	0	0.50	0
		3	0	0.07	0	0	0	0	0	0.25	0

Table 16. Calculated total abundance (number) and biomass (tonnes) of green sea urchins by site and size category in November, 2004 (incorporates estimates from unknowns). (Legal ≥ 55 mm test diameter (TD), Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD. Biomass estimates were calculated using TD-weight relationships determined from November, 2004 lab measurements for each of the three sites separately, and applied to the field survey TD measurements. * Note only one transect was sampled at the Plumper Islands).

Size Category	Stephenson Islets	Stubbs Island	Plumper Islands*
Number of Legal-sized	932,726 ± 126,467	68,223 ± 18,610	58,842
Number of Sublegal-mature	3,178,345 ± 770,214	79,154 ± 36,167	1,412,211
Number of Sublegal-immature	584,523 ± 114,051	25,254 ± 10,876	576,653
Number of all sizes	4,695,594 ± 858,768	172,631 ± 60,790	2,047,705
Biomass of Legal-size (t)	61.11 ± 8.29	6.21 ± 1.70	4.65
Biomass of Sublegal-mature (t)	71.79 ± 17.41	1.76 ± 0.81	24.58
Biomass of Sublegal-immature (t)	1.87 ± 0.37	0.06 ± 0.03	1.86
Total Biomass (t)	134.77 ± 19.29	8.03 ± 1.88	31.08

Table 17. Fishing seasons for Area 12 (where the study area is located) and harvest details for the Stephenson Islets. The quota allowed for Area 12 was 224,869 lbs (102.0 t) in both October, 2003 and November, 2004.

Fishing Season	Fishing Period for the Season	% of Area 12 Quota Harvested	Harvest Weight (t) from Stephenson Islets	Stephenson Islets % of Area 12 Total Harvest	Exploitation at Stephenson Islets
2003/2004	Nov. 1, 2003 – Mar. 1, 2004	88.8%	14.96	17.21	0.14 ± 0.02
2004/2005	Nov. 1, 2004 – Mar. 1, 2005	35.4%	7.25	20.11	0.12 ± 0.02

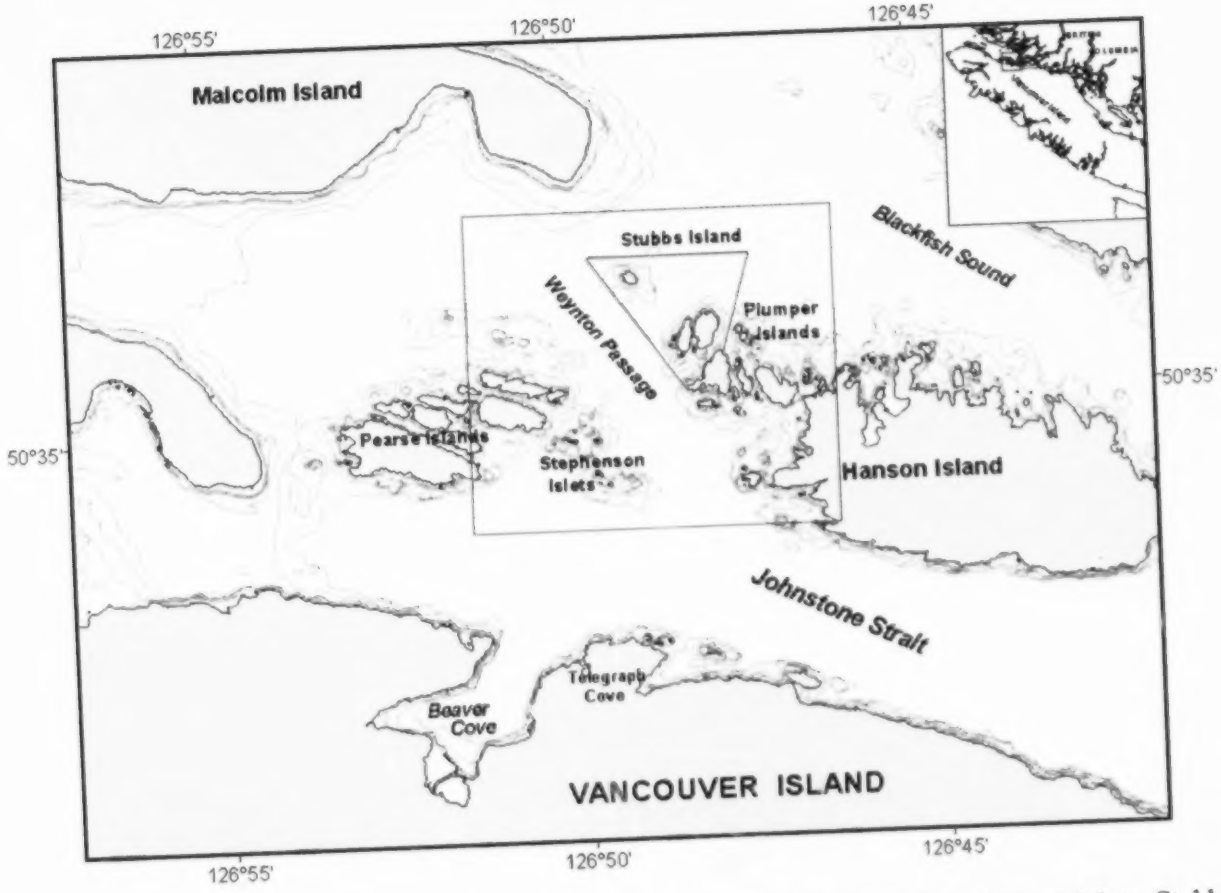

Fig. 1a. Site locations for the October, 2003 and November, 2004 green urchin surveys (Stephenson Islets, Stubbs Island and the Plumper Islands). The red border represents the boundaries of the research closure area. No commercial fishing may occur within these boundaries.

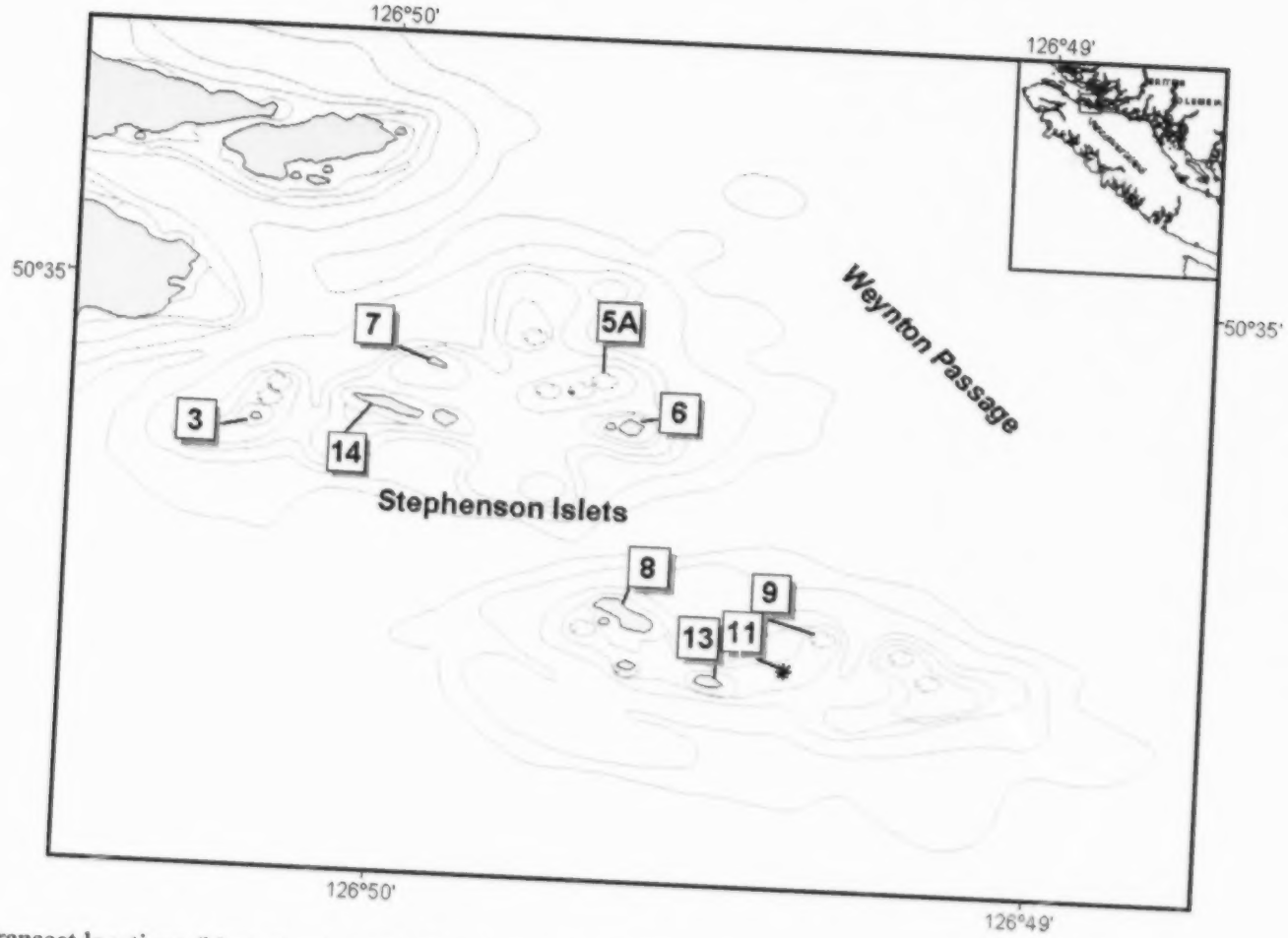

Fig. 1b. Transect locations (black lines) for the October, 2003 and November, 2004 green sea urchin surveys, Stephenson Islets.

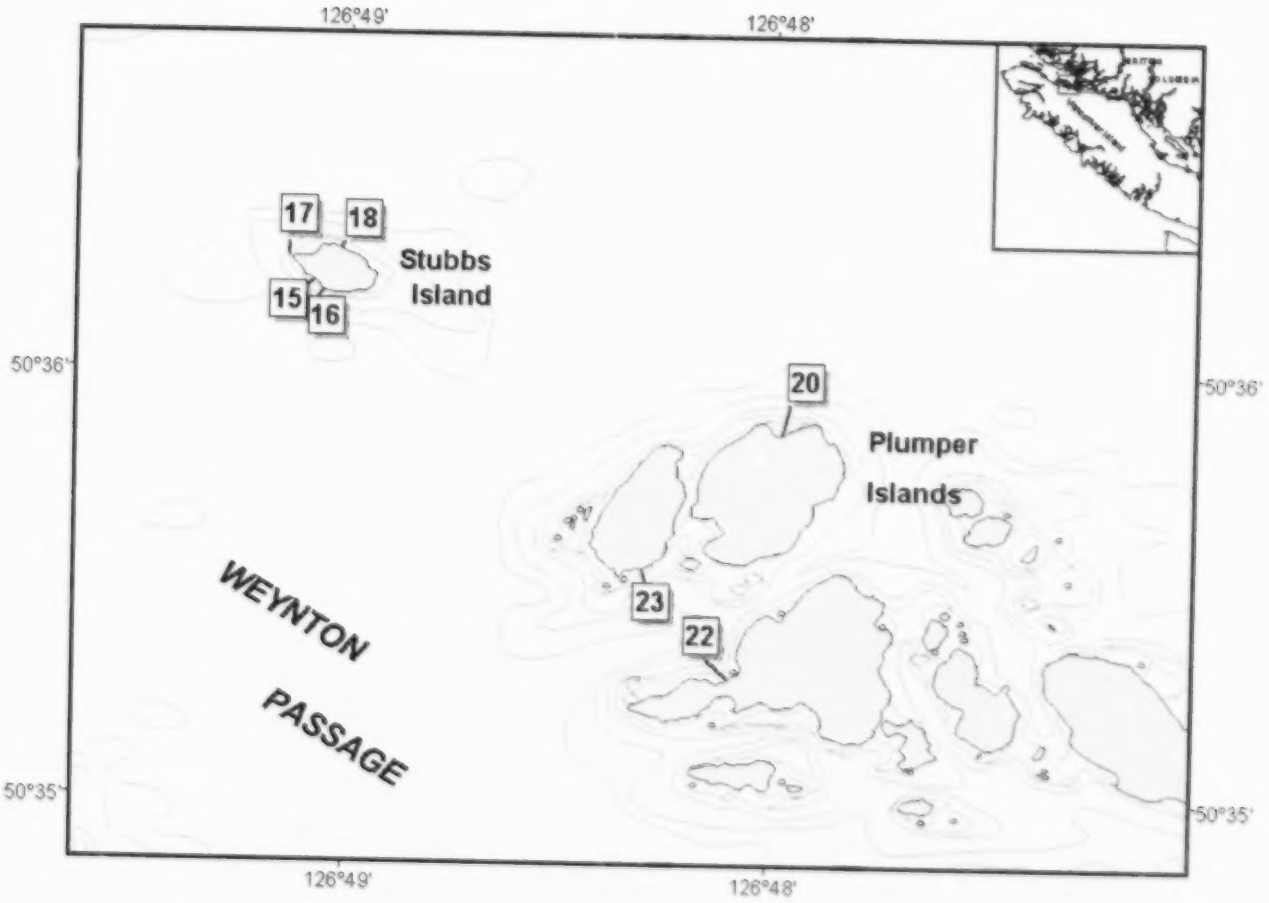

Fig. 1c. Transect locations (black lines) for the October, 2003 and November, 2004 green sea urchin surveys, Stubbs Island and the Plumper Islands.

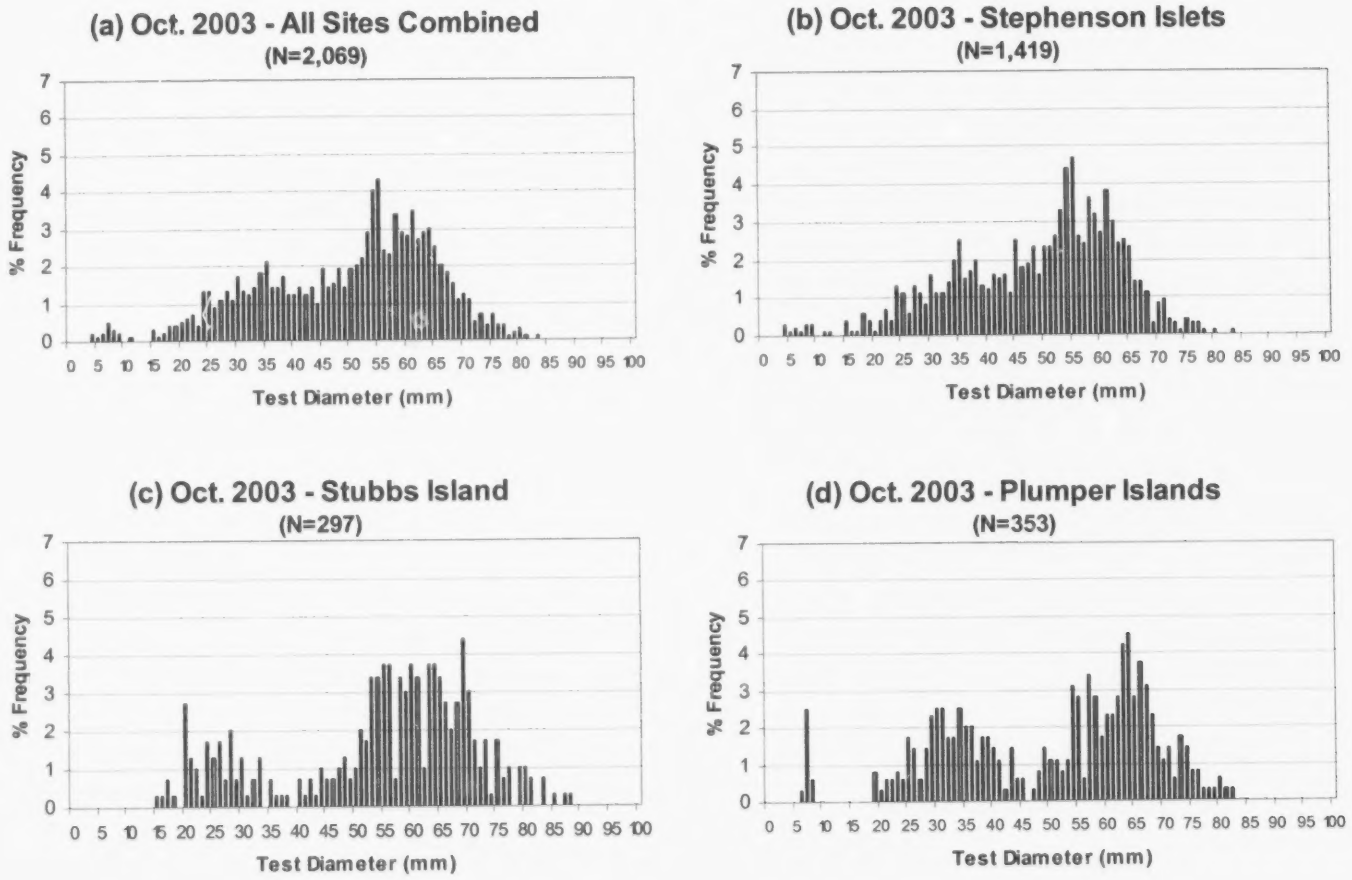

Fig. 2. Size (test diameter in millimeters) distributions of green sea urchins collected in October, 2003 from (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. Note the fishery minimum size limit is 55 mm.

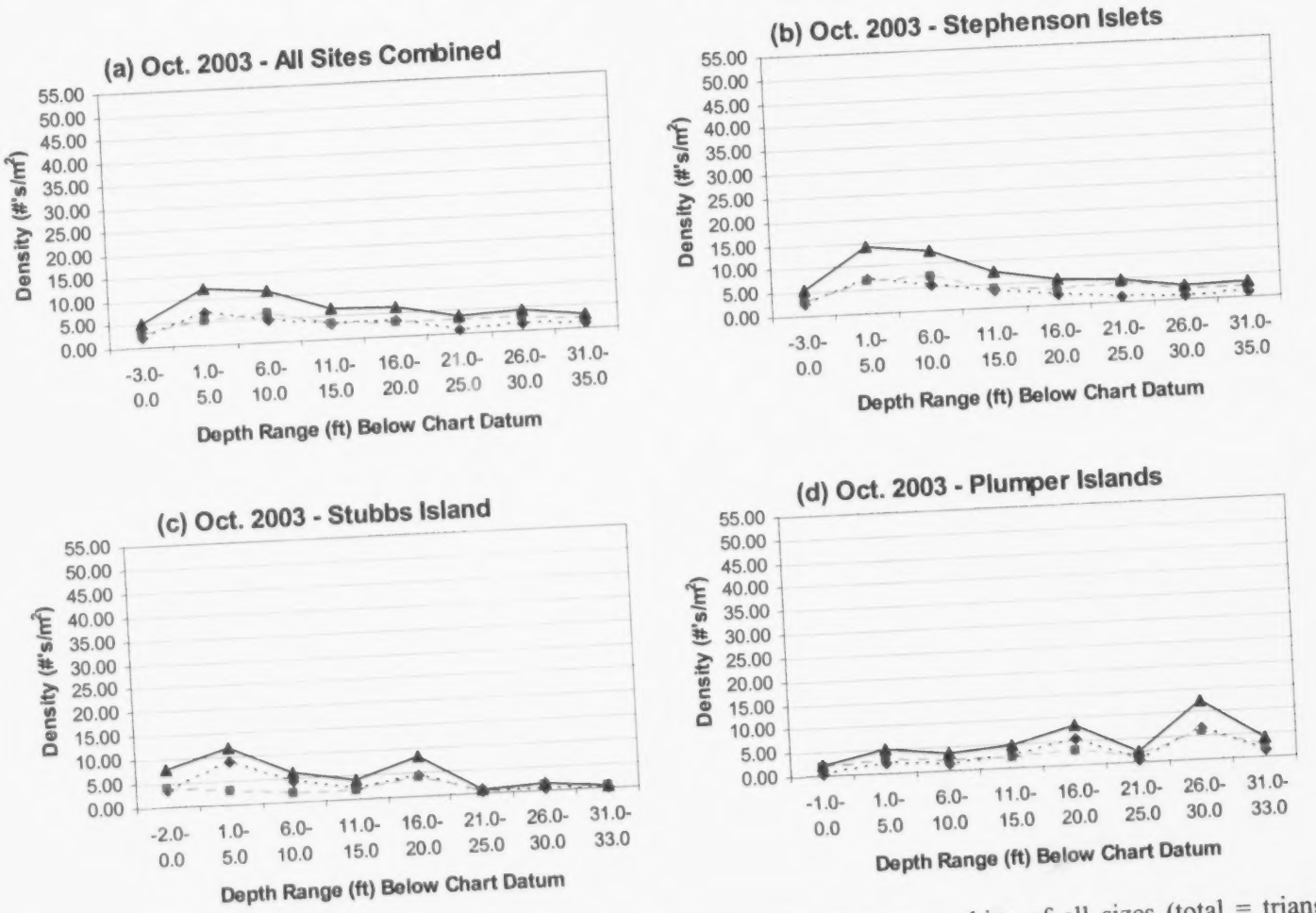

Fig. 3. October, 2003 mean densities (number per square meter) of green sea urchins of all sizes (total = triangles), legal size (diamonds), and sublegal size (squares) by depth range (feet) below Chart Datum from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. Note that the density scale is consistent for all of the "density by depth" charts between both surveys.

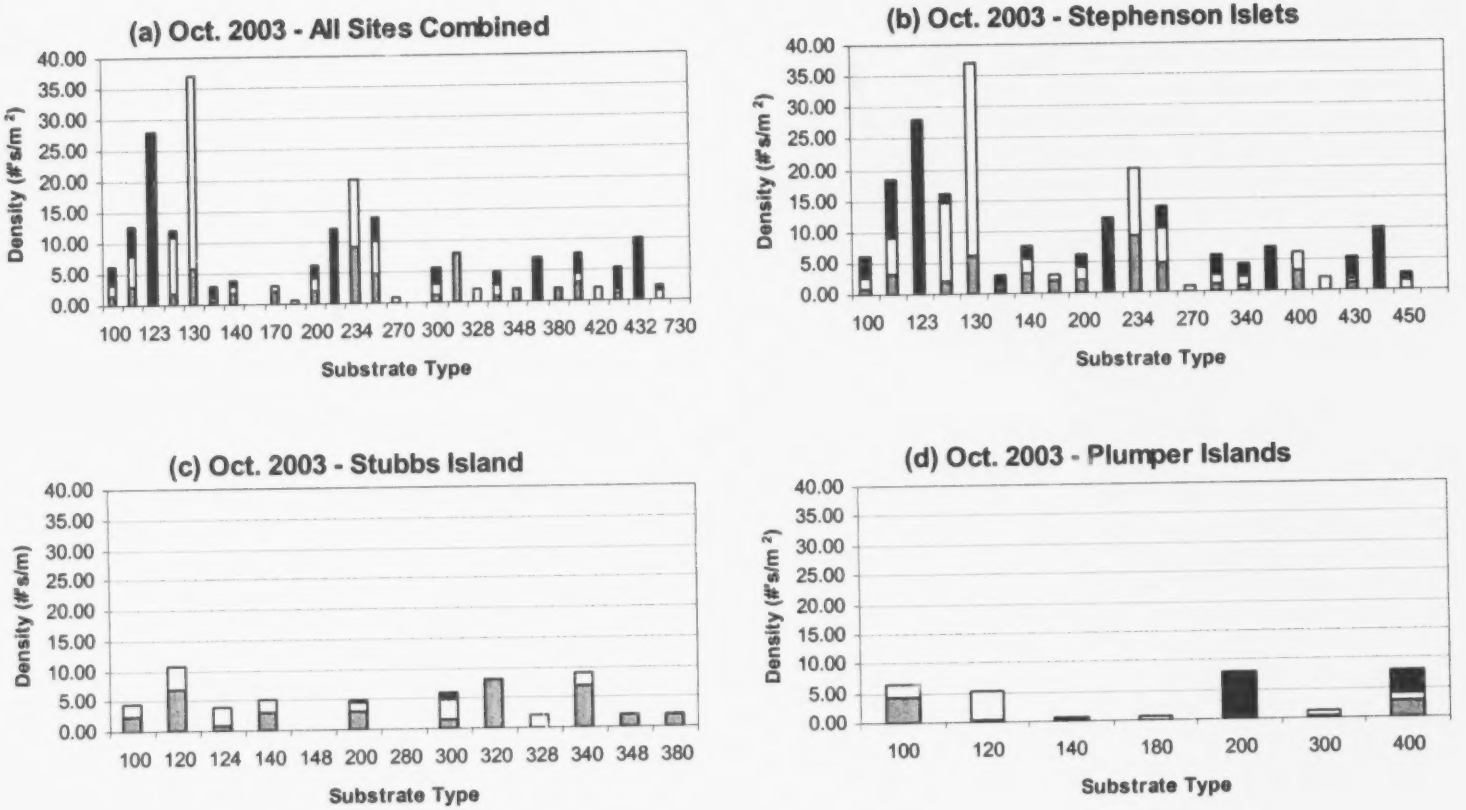

Fig. 4. October, 2003 mean densities (number per square meter) of green sea urchins of legal size (grey), sublegal size (white) and unknown size (black), by substrate type from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. See Tables 8a-d for the keys to the substrate codes. Unidentified substrates not displayed. Note that the density scale is consistent for all of the "density by substrate" charts between both surveys throughout the report.

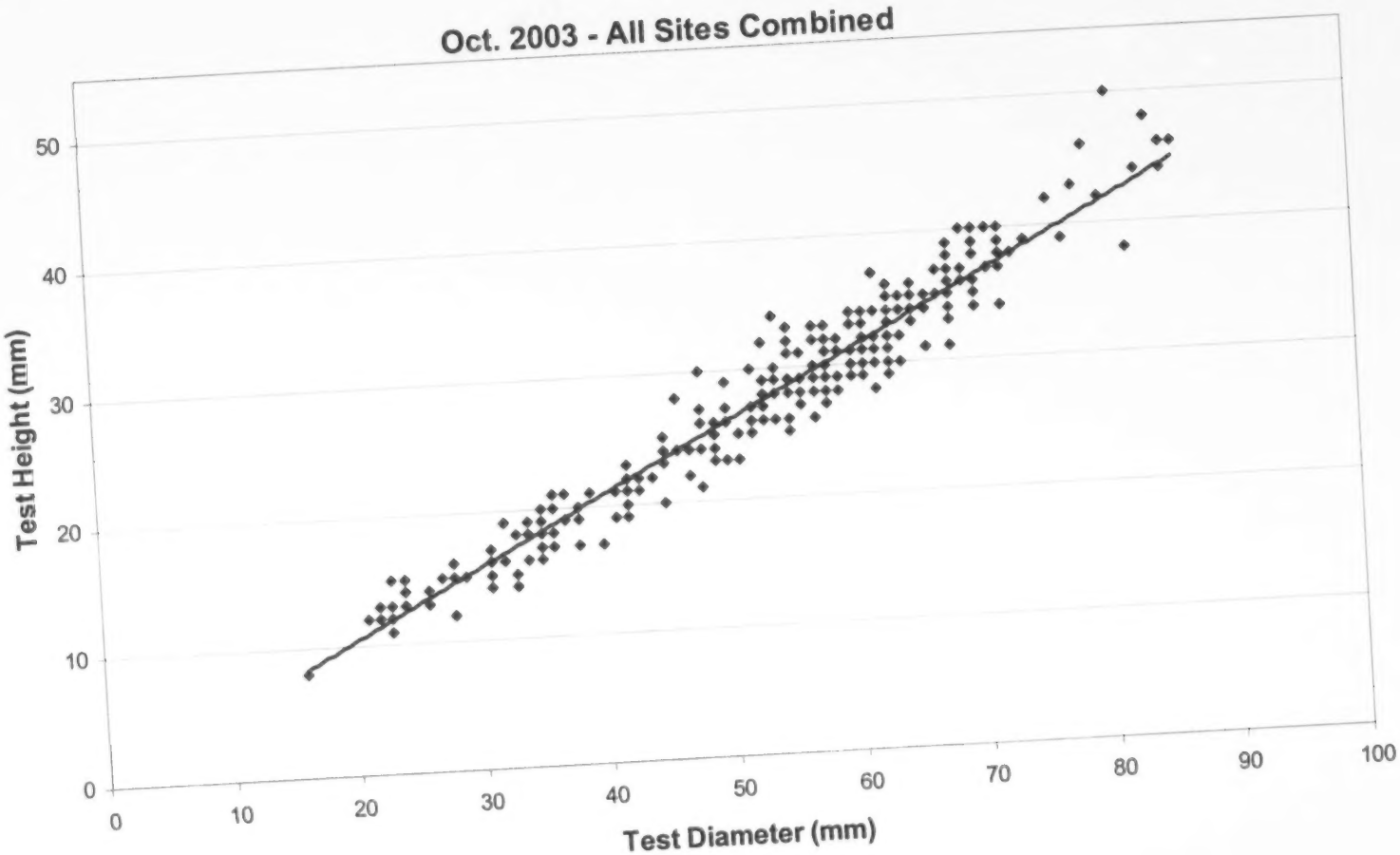

Fig. 5. Relationship between green sea urchin test diameter (TD, in millimeters) and test height (millimeters) in October, 2003, for all sites combined: TEST HEIGHT (mm) = $0.5153(TD^{1.0023})$, $R^2 = 0.9495$, n=286.

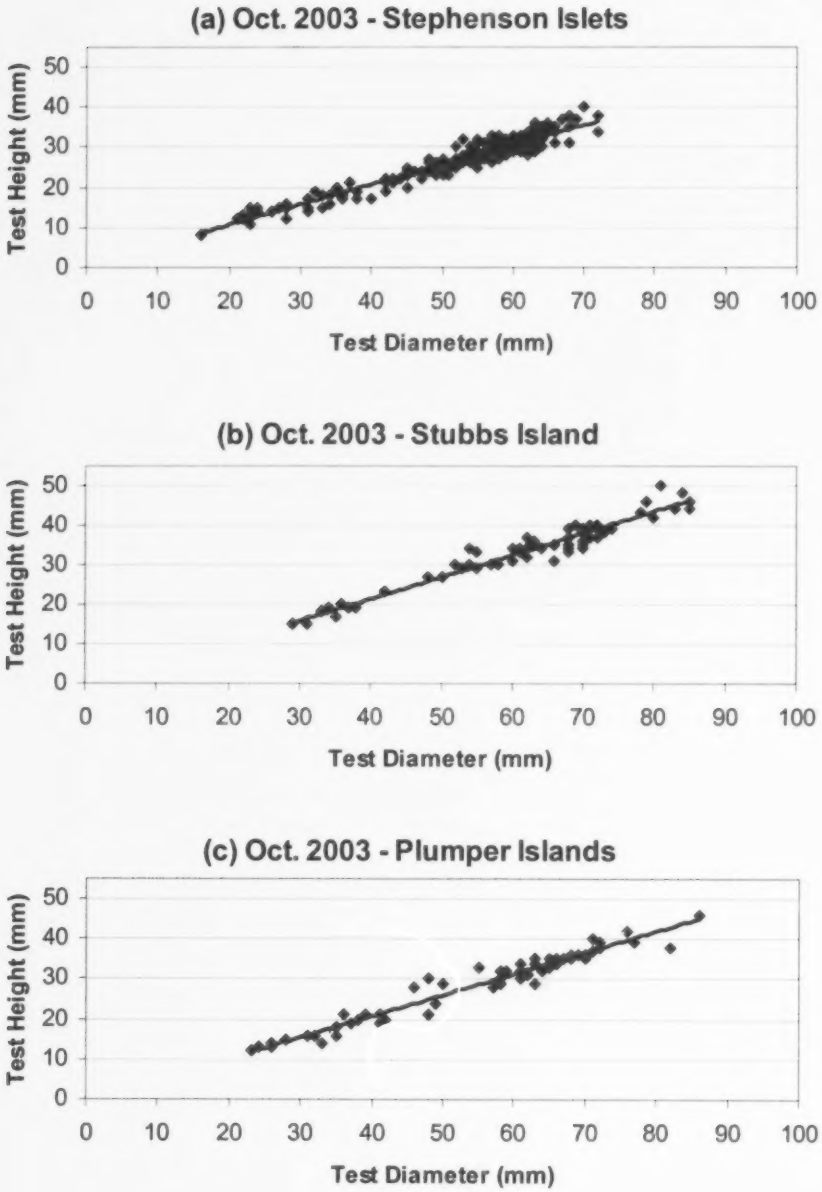
(a) Oct. 2003 - Stephenson Islets
Test Height (mm)
Test Diameter (mm)
(b) Oct. 2003 - Stubbs Island
Test Height (mm)
Test Diameter (mm)
(c) Oct. 2003 - Plumper Islands
Test Height (mm)
Test Diameter (mm)

Fig. 6. Relationships between green sea urchin test diameter (TD, in millimeters) and test height (millimeters) calculated in October, 2003 for:
(a) Stephenson Islets (TEST HEIGHT (mm) = $0.5971(TD^{0.9613})$, $R^2 = 0.9420$, n=169);
(b) Stubbs Island (TEST HEIGHT (mm) = $0.4768(TD^{1.0300})$, $R^2 = 0.9556$, n=58);
(c) Plumper Islands (TEST HEIGHT (mm) = $0.4861(TD^{1.0170})$, $R^2 = 0.9597$, n=59).

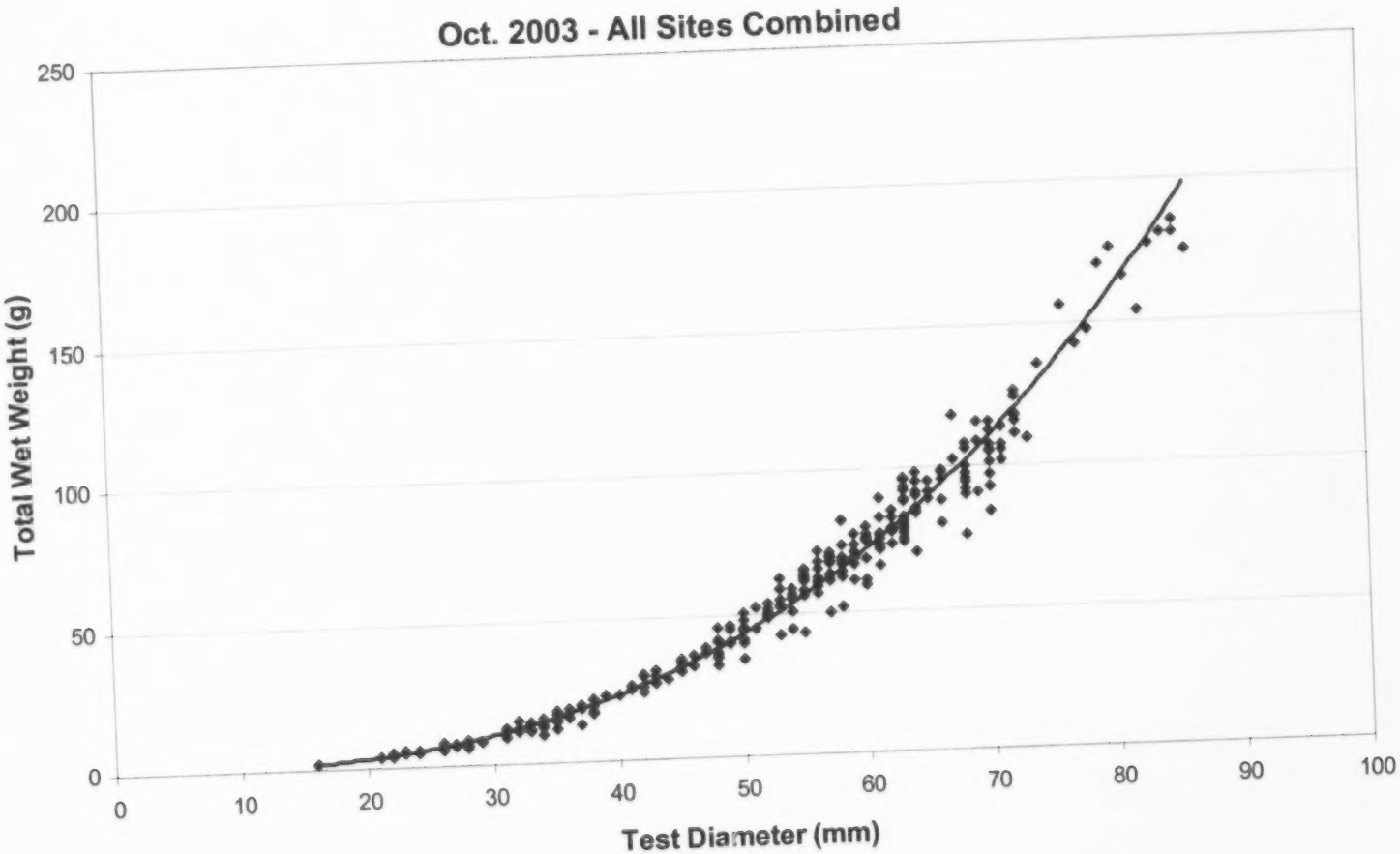

Fig. 7. Relationship between green sea urchin test diameter (TD, in millimeters) and total wet weight (grams) in October, 2003, for all sites combined: TOTAL WET WEIGHT (g) = $0.0007(TD^{2.8180})$, $R^2 = 0.9873$, n=286.

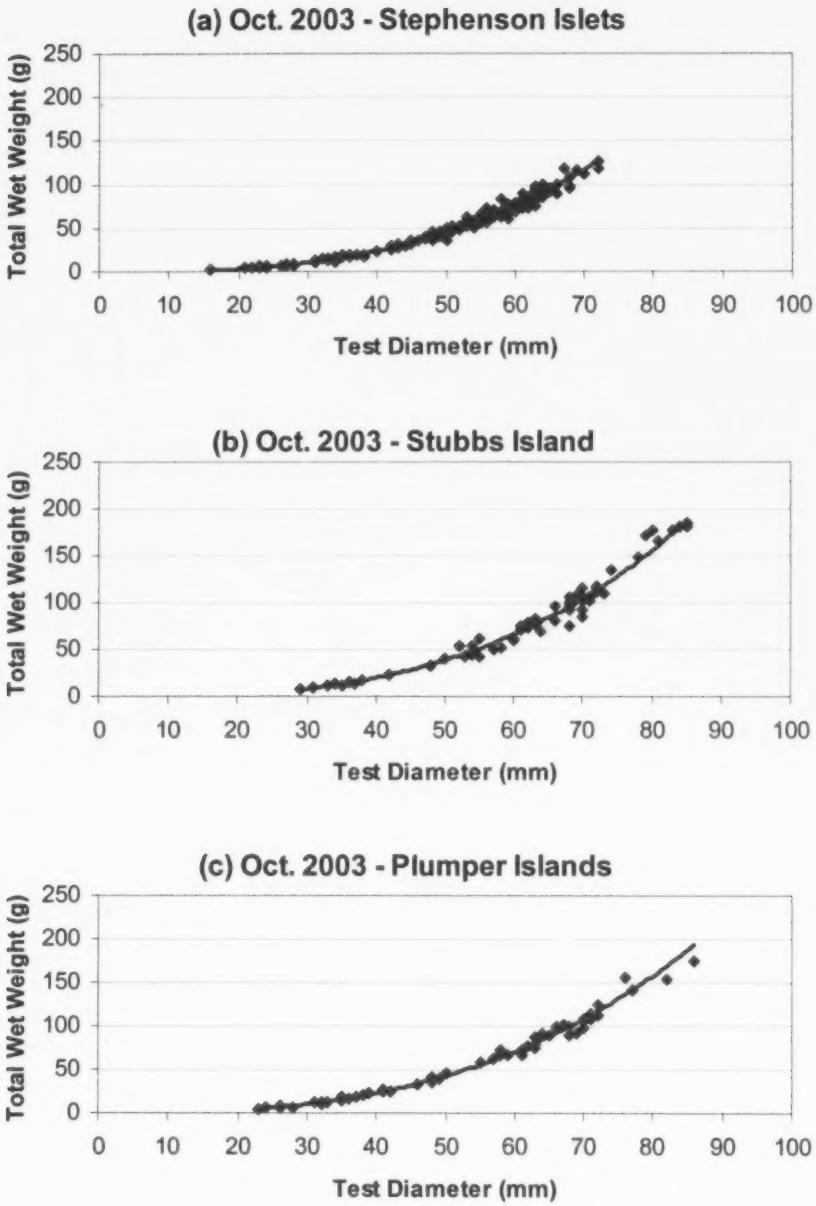

Fig. 8. Relationships between green sea urchin test diameter (TD, in millimeters) and total wet weight (grams) calculated in October, 2003 for:
(a) Stephenson Islets (TOTAL WET WEIGHT (g) = $0.0006(TD^{2.0540})$, $R^2 = 0.9910$, n=169);
(b) Stubbs Island (TOTAL WET WEIGHT (g) = $0.0003(TD^{2.9723})$, $R^2 = 0.9856$, n=58);
(c) Plumper Islands (TOTAL WET WEIGHT (g) = $0.0007(TD^{2.7976})$, $R^2 = 0.9918$, n=59).

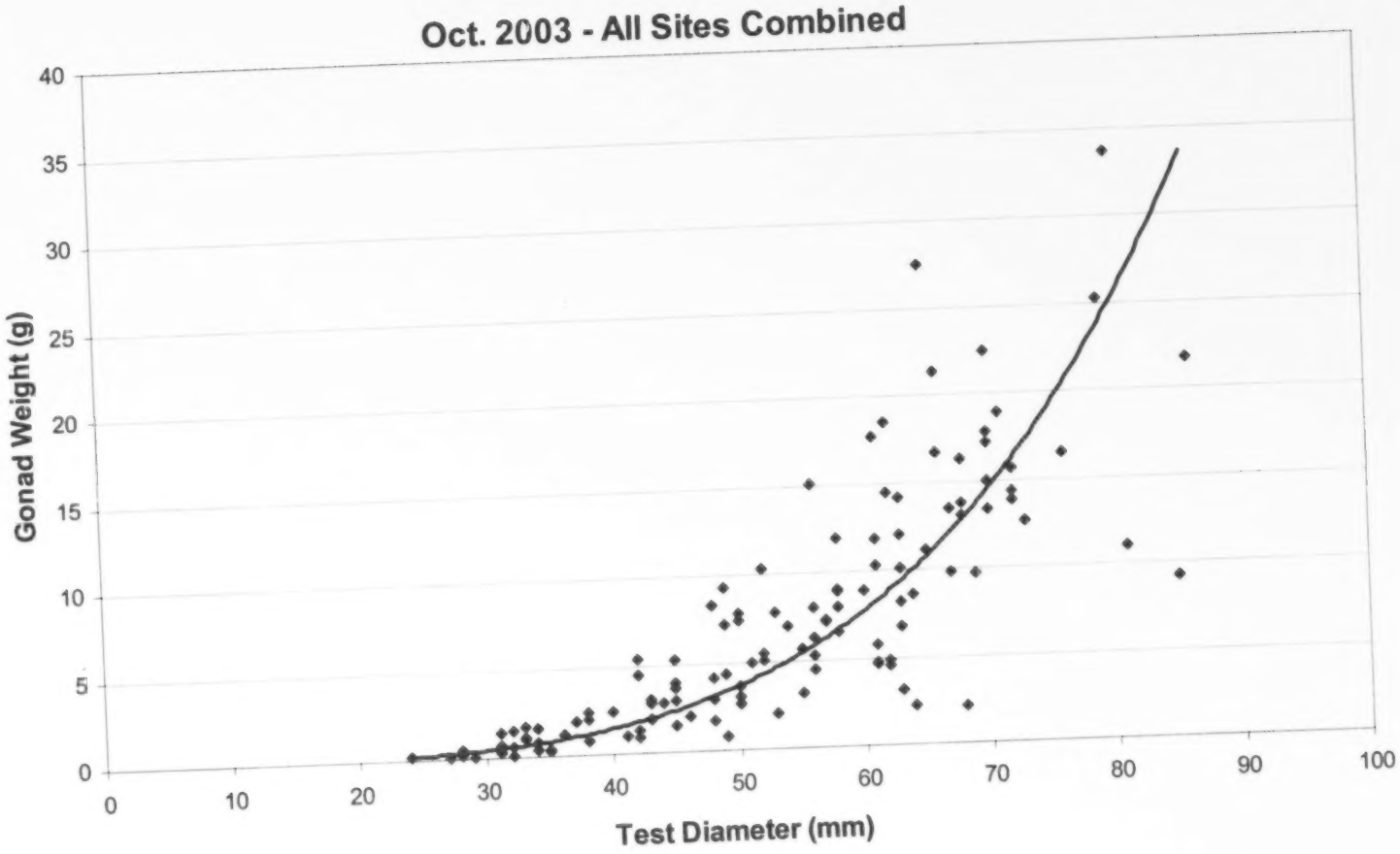

Fig. 9. Relationship between green sea urchin test diameter (TD, in millimeters) and gonad weight (grams) in October, 2003, calculated from all sites combined: GONAD WEIGHT (g) = $4 \times 10^{-7}(TD^{4.0845})$; $R^2 = 0.8014$, n = 127.

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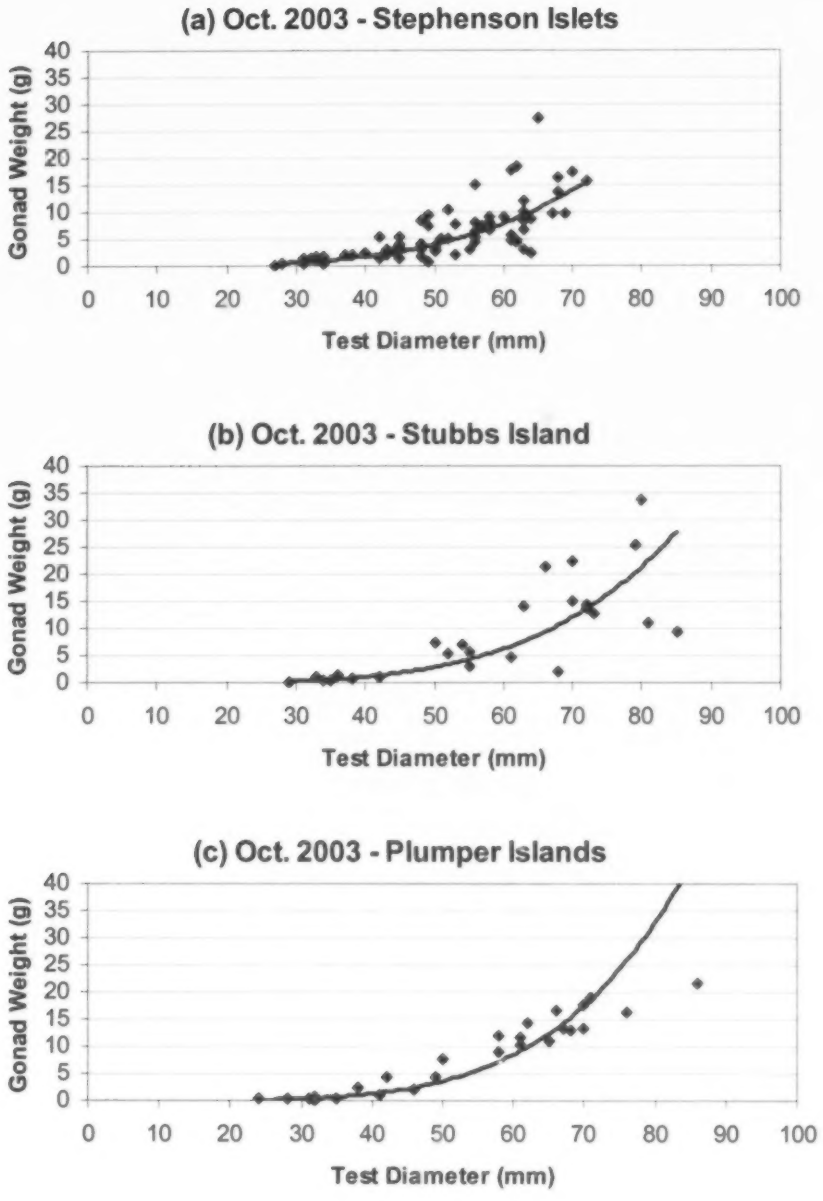
(a) Oct. 2003 - Stephenson Islets
Gonad Weight (g)
Test Diameter (mm)
(b) Oct. 2003 - Stubbs Island
Gonad Weight (g)
Test Diameter (mm)
(c) Oct. 2003 - Plumper Islands
Gonad Weight (g)
Test Diameter (mm)

Fig. 10. Relationships between green sea urchin test diameter (TD, in millimeters) and gonad weight (grams) calculated in October, 2003 for:
(a) Stephenson Islets (GONAD WEIGHT (g) = 2×10^{-6} ($TD^{3.7479}$), $R^2 = 0.7485$, n=75);
(b) Stubbs Island (GONAD WEIGHT (g) = 1×10^{-7} ($TD^{4.3093}$), $R^2 = 0.8185$, n=25);
(c) Plumper Islands (GONAD WEIGHT (g) = 4×10^{-8} ($TD^{4.7031}$), $R^2 = 0.9022$, n=27).
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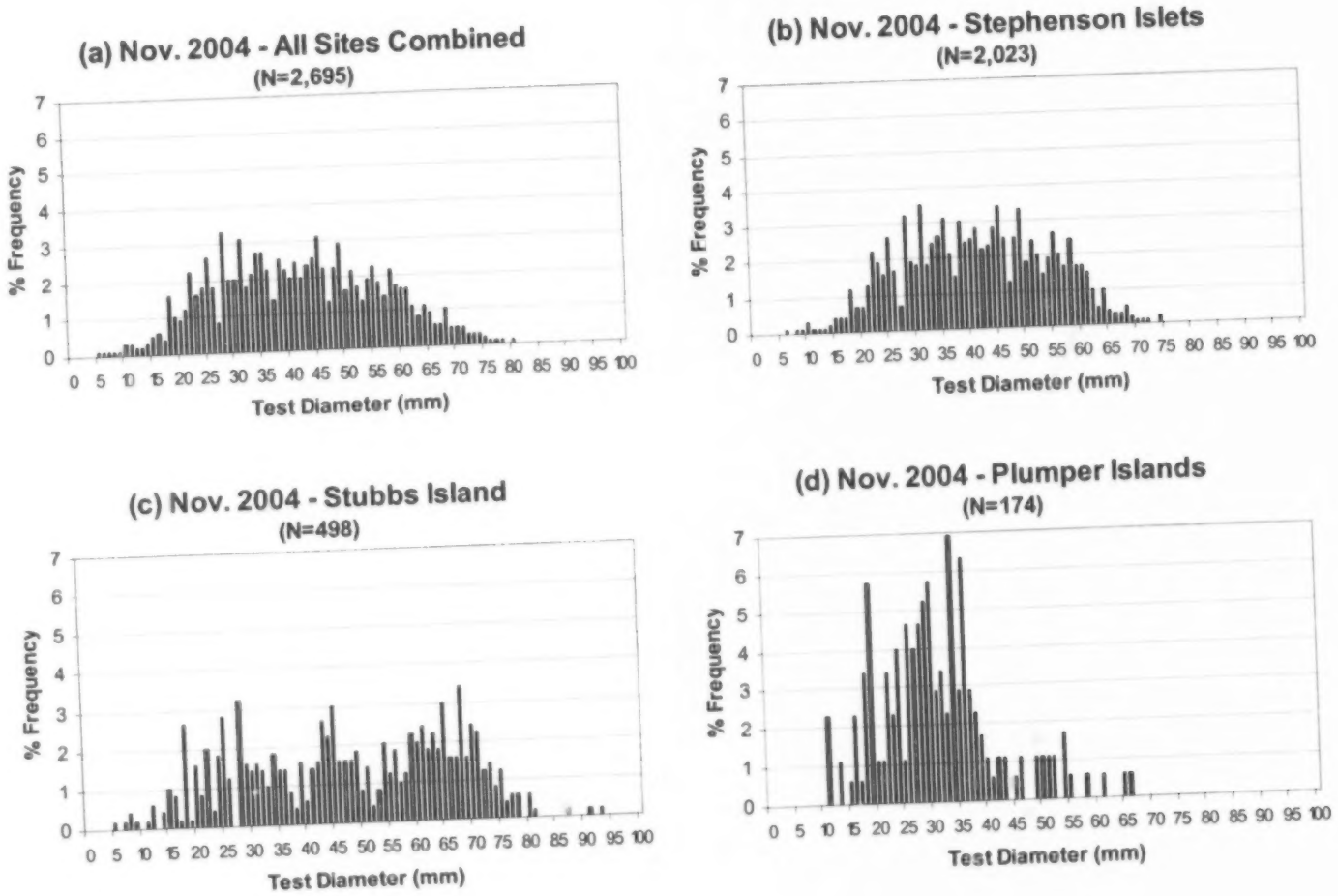

Fig. 11. Size (test diameter in millimeters) distribution of green sea urchins collected in November, 2004 from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. Note the fishery minimum size limit is 55 mm.

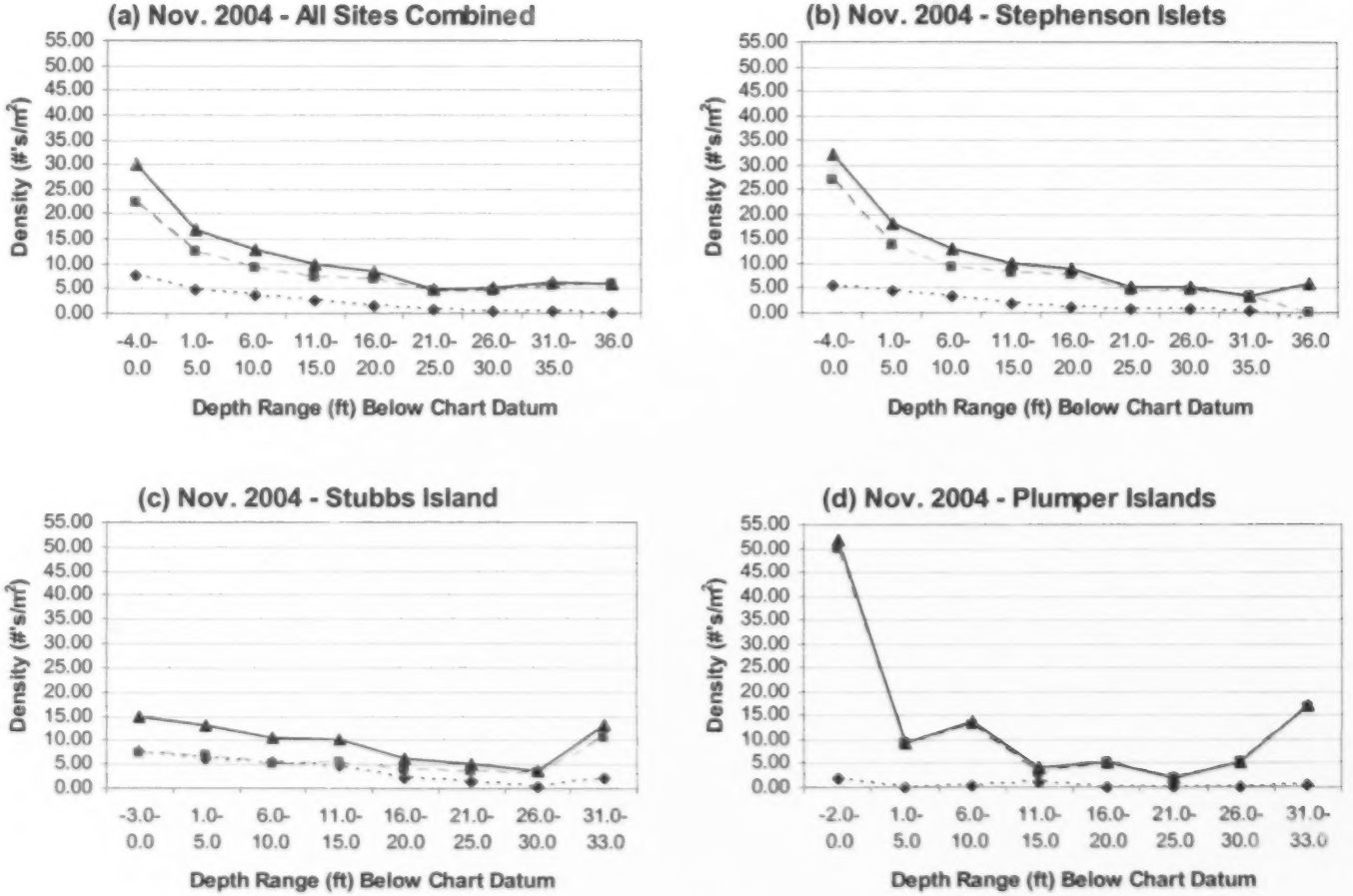

Fig. 12. November, 2004 mean densities (number per square meter) of green sea urchins of all sizes (total = triangles), legal size (diamonds), and sublegal size (squares) by depth range (feet) below Chart Datum from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. Note that the unmeasured urchins ("unknowns") have been proportioned into the legal and sublegal density estimates by using the ratios from measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns. Note that the density scale is consistent for all of the "density by depth" charts between both surveys.

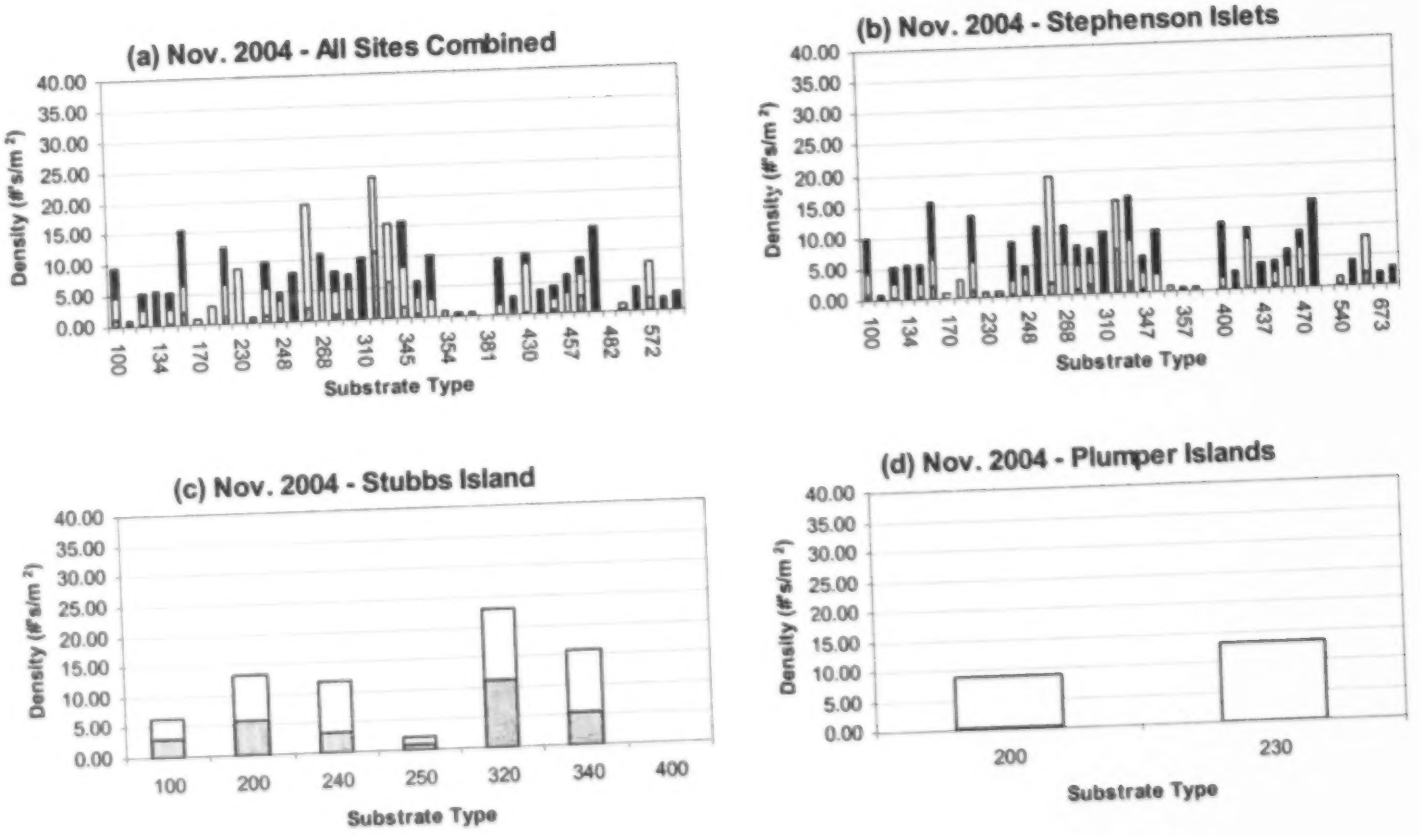

Fig. 13. November, 2004 mean densities (number per square meter) of green sea urchins of legal size (grey), sublegal size (white) and unknown size (black), by substrate type from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. See Tables 15a-d for the keys to the substrate codes. Unidentified substrates not displayed. Note that the density scale is consistent for all of the "density by substrate" charts between both surveys throughout the report.

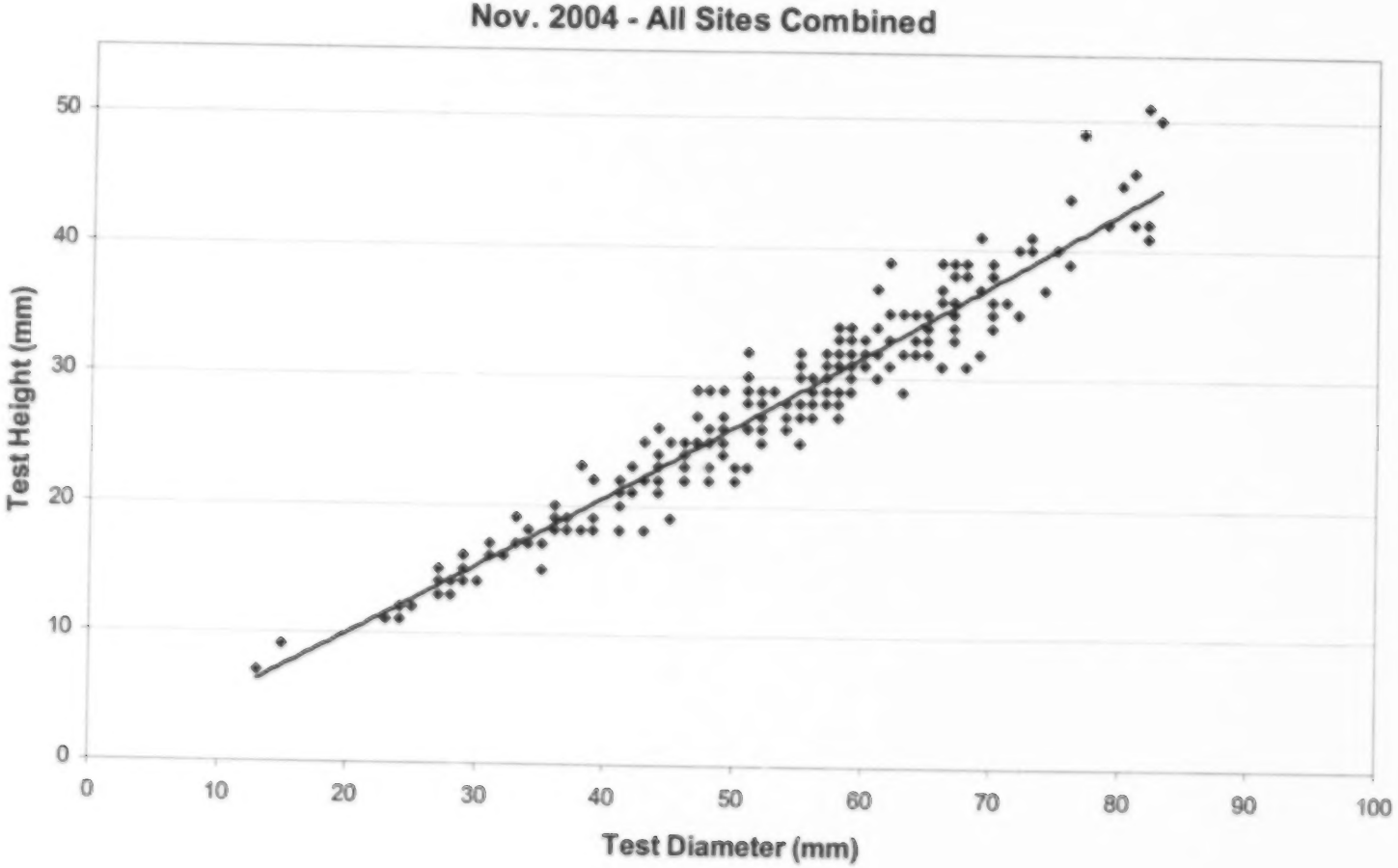

Fig. 14. Relationship between green sea urchin test diameter (TD, in millimeters) and test height (millimeters) in November, 2004, for all sites combined: TEST HEIGHT (mm) = $0.4232(TD^{1.0539})$, $R^2 = 0.9509$, n=236.

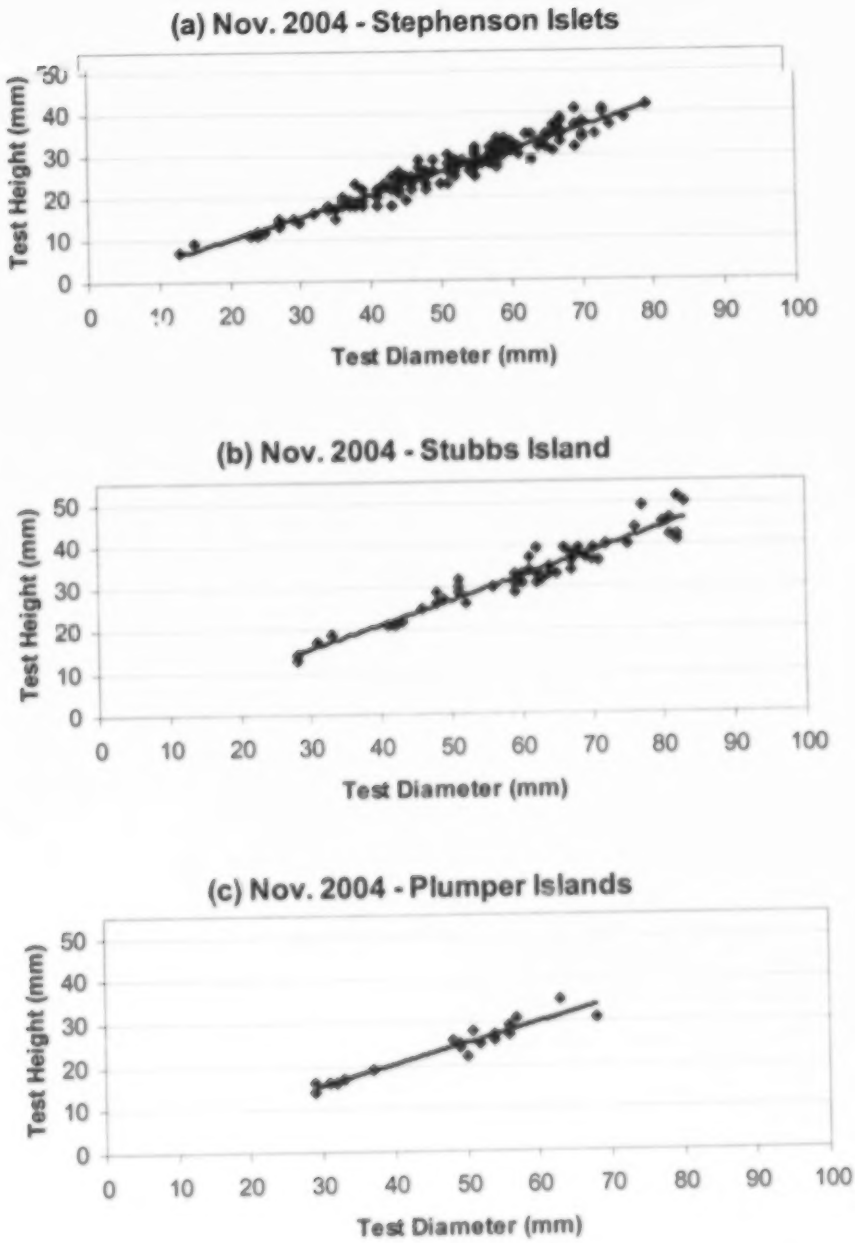
(a) Nov. 2004 - Stephenson Islets
Test Height (mm)
Test Diameter (mm)
(b) Nov. 2004 - Stubbs Island
Test Height (mm)
Test Diameter (mm)
(c) Nov. 2004 - Plumper Islands
Test Height (mm)
Test Diameter (mm)

Fig. 15. Relationships between green sea urchin test diameter (TD, in millimeters) and test height (millimeters) calculated in November, 2004 for:
(a) Stephenson Islets (TEST HEIGHT (mm) = $0.4500(TD^{1.0362})$, $R^2 = 0.9510$, n=162);
(b) Stubbs Island (TEST HEIGHT (mm) = $0.4174(TD^{1.0647})$, $R^2 = 0.9424$, n=55);
(c) Plumper Islands (TEST HEIGHT (mm) = $0.5830(TD^{0.9628})$, $R^2 = 0.9439$, n=19).

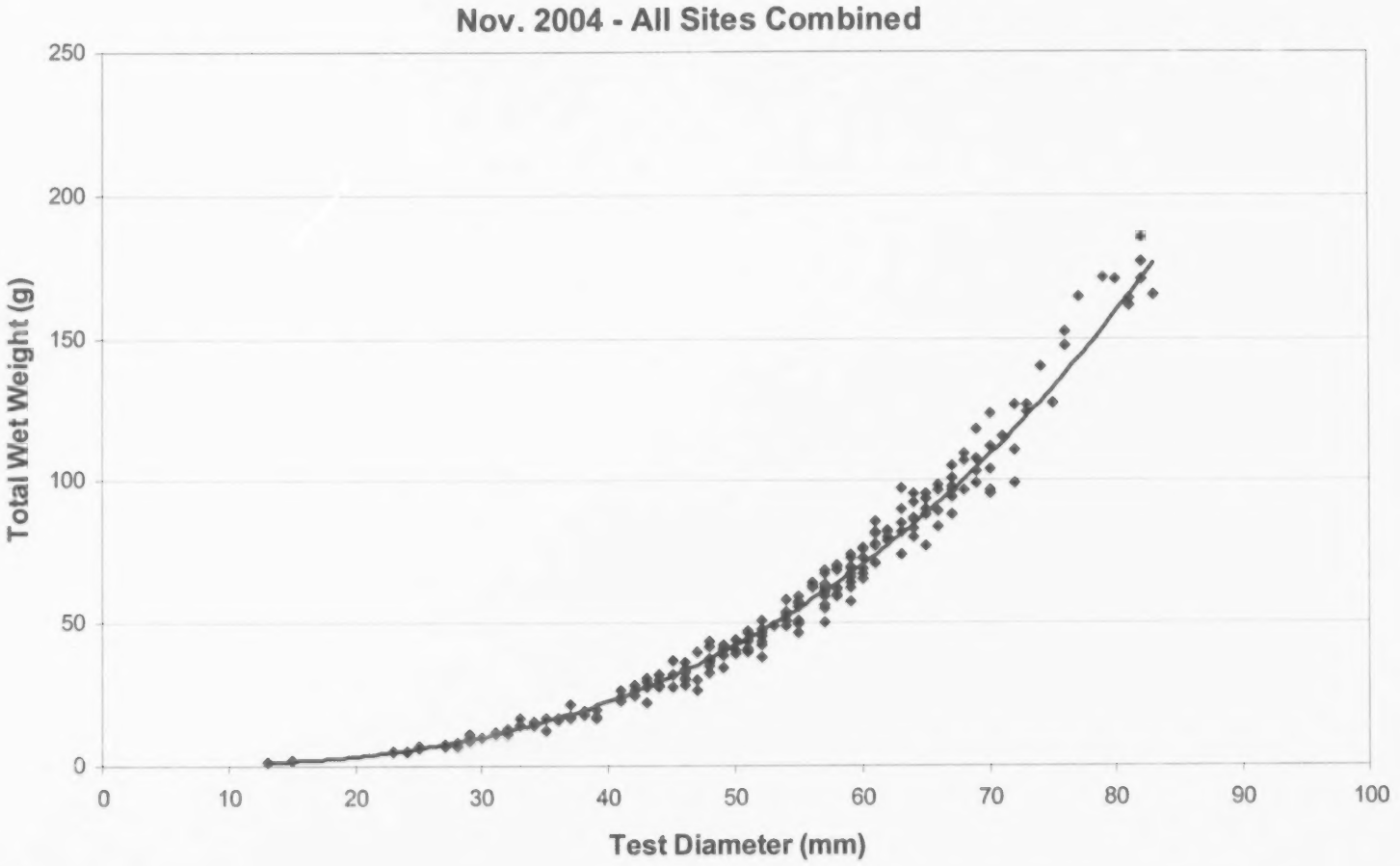

Fig. 16. Relationship between green sea urchin test diameter (TD, in millimeters) and total wet weight (grams) in November, 2004, for all sites combined: TOTAL WET WEIGHT (g) = $0.0007(TD^{2.8286})$, $R^2 = 0.9899$, n=236.

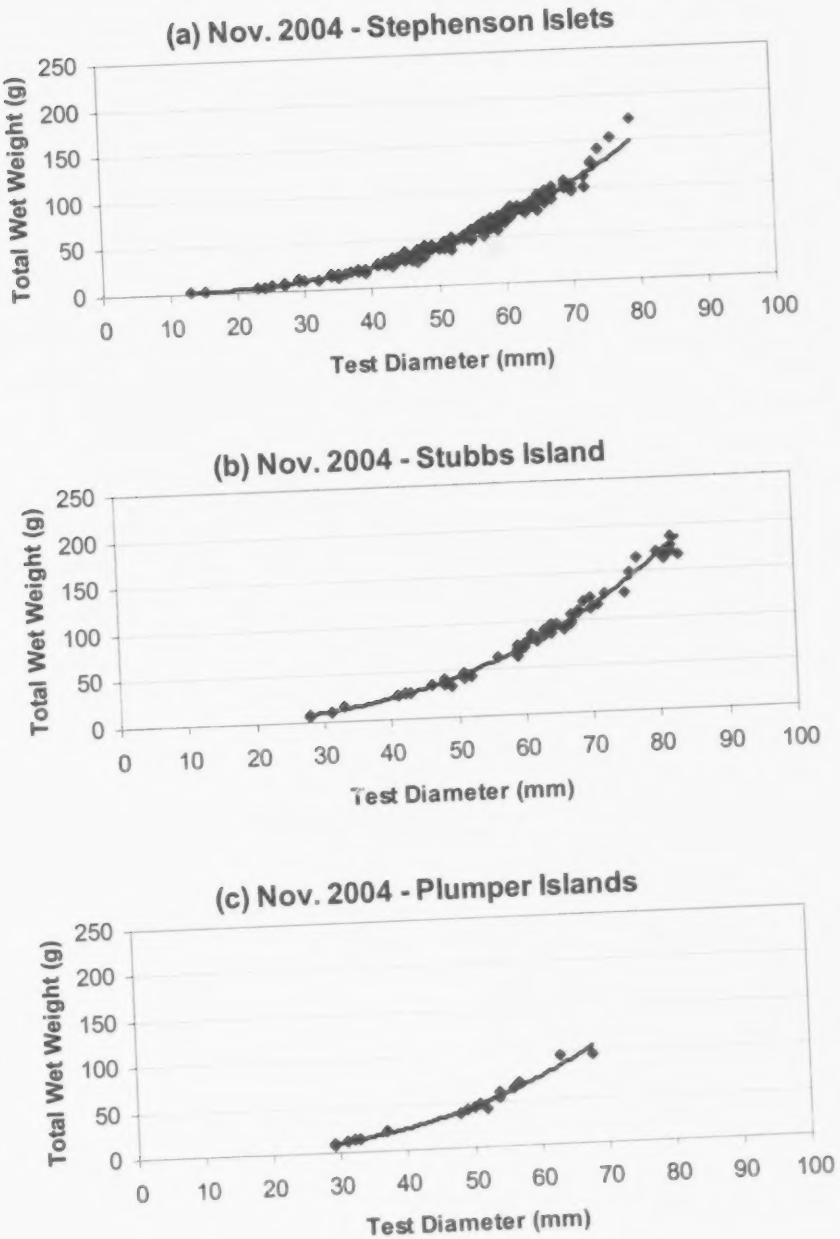

Fig. 17. Relationships between green sea urchin test diameter (TD, in millimeters) and total wet weight (grams) calculated in November, 2004 for:
(a) Stephenson Islets (TOTAL WET WEIGHT (g) = $0.0007(TD^{2.7952})$, $R^2 = 0.9900$, n=162);
(b) Stubbs Island (TOTAL WET WEIGHT (g) = $0.0005(TD^{2.8833})$, $R^2 = 0.9908$, n=55);
(c) Plumper Islands (TOTAL WET WEIGHT (g) = $0.0007(TD^{2.8270})$, $R^2 = 0.9917$, n=19).

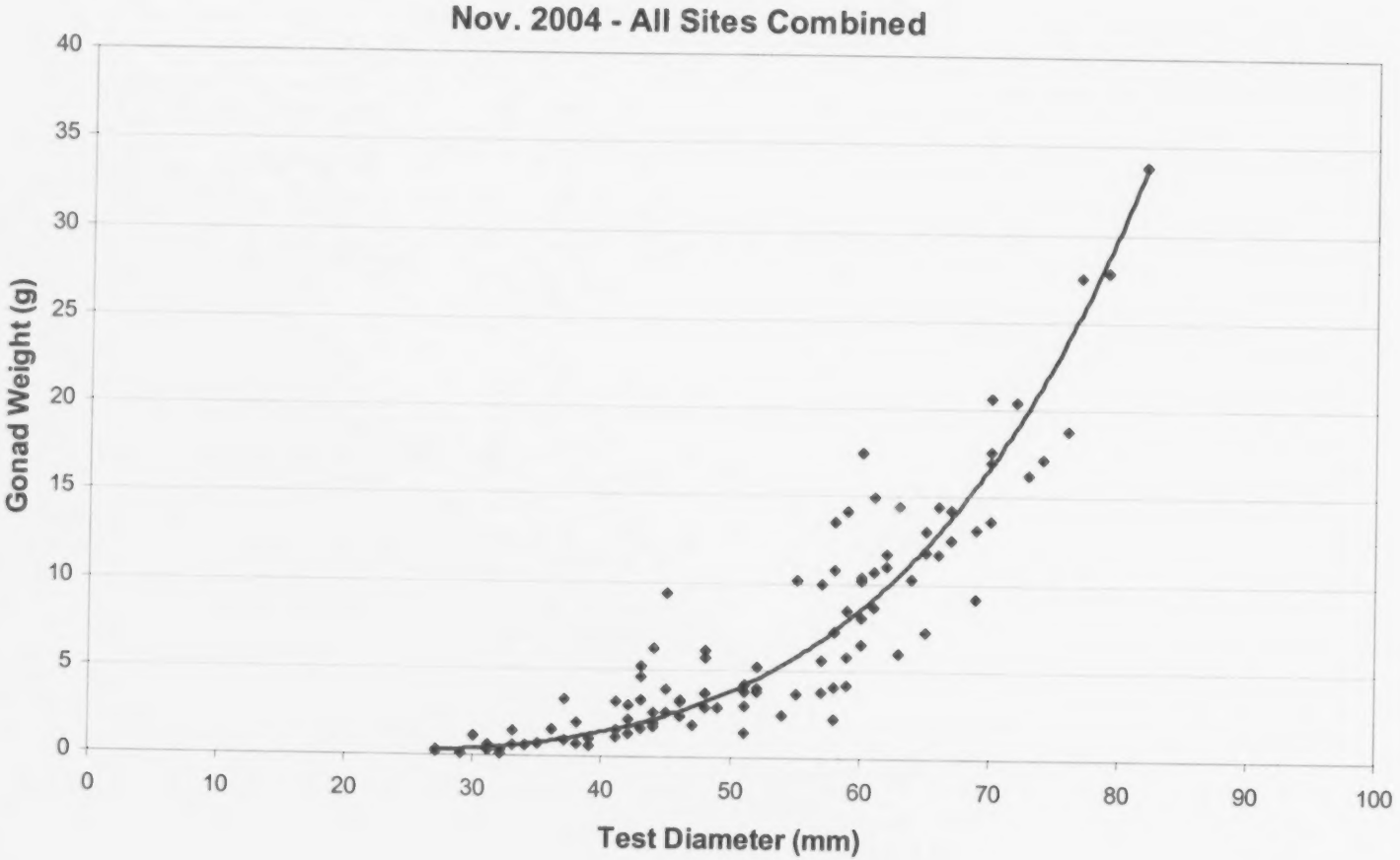

Fig. 18. Relationship between green sea urchin test diameter (TD, in millimeters) and gonad weight (grams) in November, 2004, calculated from all sites combined: GONAD WEIGHT (g) = $1 \times 10^{-7}(TD^{4.4314})$; $R^2 = 0.8496$, n = 102.

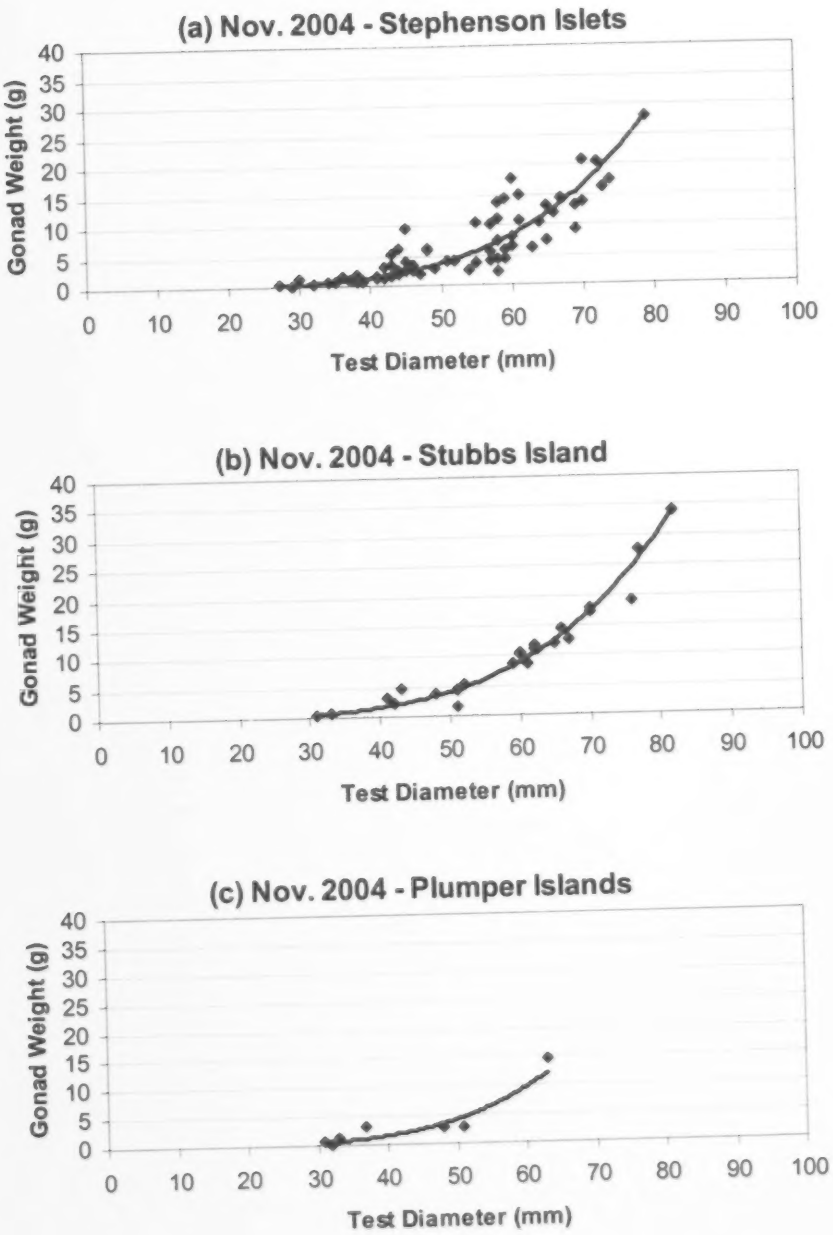
(a) Nov. 2004 - Stephenson Islets
Gonad Weight (g)
Test Diameter (mm)
(b) Nov. 2004 - Stubbs Island
Gonad Weight (g)
Test Diameter (mm)
(c) Nov. 2004 - Plumper Islands
Gonad Weight (g)
Test Diameter (mm)

Fig. 19. Relationships between green sea urchin test diameter (TD, in millimeters) and gonad weight (grams) calculated in November, 2004 for:
(a) Stephenson Islets (GONAD WEIGHT (g) = 1×10^{-6} ($TD^{3.8609}$), $R^2 = 0.7944$, n=73);
(b) Stubbs Island (GONAD WEIGHT (g) = 6×10^{-8} ($TD^{4.6452}$), $R^2 = 0.8671$, n=35);
(c) Plumper Islands (GONAD WEIGHT (g) = 1×10^{-7} ($TD^{4.4253}$), $R^2 = 0.7869$, n=33.